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Minimum Aviation System Performance Standards for ADS-B Traffic Surveillance Systems and Applications (ATSSA)

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FOREWORD

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications (ASA). This document is intended to specify requirements for and describe assumptions for all subsystems supporting the operational application of ASA, e.g., Automatic Dependent Surveillance - Broadcast (ADS-B), Airborne Surveillance and Separation Assurance Processing (ASSAP), and Cockpit Display of Traffic Information (CDTI).

These standards specify characteristics that should be useful to designers, installers, manufacturers, service providers and users for systems intended for operational use within the United States National Airspace System (NAS). Where systems are global in nature, the system may have international applications that are taken into consideration.

Compliance with these standards is recommended as one means of assuring that the system and each subsystem will perform its intended function(s) satisfactorily under conditions normally encountered in routine aeronautical operations for the environments intended. These MASPS may be implemented by one or more regulatory documents or advisory documents (e.g., certifications, authorizations, approvals, commissioning, advisory circulars, notices, etc.) and may be implemented in part or in total. Any regulatory application of this document is the sole responsibility of the appropriate governmental agencies.

<u>Chapter 1</u> of this document describes the Aircraft Surveillance Applications system and provides information needed to understand the rationale for function characteristics and requirements. This section describes typical applications and operational goals, as envisioned by members of RTCA Special Committee 186, and establishes the basis for the standards stated in Chapters 2 through 4. Definitions and assumptions (**ASSUMP #**) essential to the proper understanding of this document are also provided in this section, and are summarized in §3.7.1. Additional definitions are provided in Appendix A.

<u>Chapter 2</u> describes minimum system performance requirements for the ASA system under standard operating and environmental conditions. ASA functional requirements and associated performance requirements are provided.

<u>Chapter 3</u> contains the minimum performance requirements for each subsystem that is a required element of the minimum system performance specified in Chapter 2, as well as the interface requirements between these subsystems. Assumptions (**ASSUMP #**) about expected standards for systems external to ASA are also documented where they have been made and are summarized in §3.7.1.

<u>Chapter 4</u> contains the minimum performance requirements for each ASSAP system application requiring the processing of ADS-B Messages that have been received and assembled into reports. The applications are grouped into broad categories of situational awareness, spacing applications, and separation applications.

The appendices are as follows:

A: Acronyms and Definitions of Terms
B: Bibliography and References

C: Derivation of Link Quality Requirements for Future Applications
D: Receive Antenna Coverage Constraints
E: Performance Requirements to Support Air-to-Air Use of Target State Reports
F: Derivation of Track Acquisition and Maintenance Requirements
G: Future Air-Referenced Velocity (ARV) Broadcast Conditions

The word "sub-function" as used in this document includes all components that make up a major independent, necessary and essential functional part of the system (i.e., a subsystem) so that the system can properly perform its intended function(s). If the system, including any sub-functions, includes computer software or electronic hardware, the guidelines contained in RTCA DO-178B [17] and RTCA DO-254 [32] should be considered even for non-aircraft applications.

1.2 System Overview

Today's airspace system provides separation assurance for aircraft operating under Instrument Flight Rules (IFR) via air traffic control and air traffic services (ATC/ATS), which are ground-based. These services utilize ground radar surveillance (primary and secondary surveillance radars), controller radar displays, air route infrastructure, airspace procedures including flight crew see and avoid, and VHF voice communications to assure separation standards are maintained. In the event of failure of this separation assurance system, aircraft equipped with Airborne Collision Avoidance Systems (ACAS), i.e., TCAS, are warned of potential mid-air collisions as a safety back up.

In order to accommodate expected increases in air traffic, a future separation assurance system is evolving using new technologies and automation processing support that is expected to enable the delegation of certain spacing or separation tasks to the flight deck. ASA represents the aircraft-based portion of this future separation assurance system. A wide range of separation assurance applications are expected to be developed over time that will enable enhanced airspace operations. These enhanced operations are intended to provide improved operational efficiencies, such as increased system capacity and throughput, while maintaining or improving air safety. Both aircraft-based and ground-based applications are discussed in this document.

1.2.1 Definition of Aircraft Surveillance Applications

The Aircraft Surveillance Applications (ASA) system comprises a number of flight-deck-based aircraft surveillance and separation assurance capabilities that may directly provide flight crews with surveillance information, as well as surveillance-based guidance and alerts. Surveillance information consists of position and other state data about other aircraft and surface vehicles and obstacles when on or near the airport surface.

ASA applications are intended to both enhance safety and increase the capacity and efficiency of the air transportation system. Safety will be enhanced by providing improved traffic situational awareness to pilots, as well as capabilities to assist in conflict prevention, conflict detection, and 4-D conflict resolution. Capacity and efficiency will be enhanced by enabling aircraft to fly closer to one another and potentially delegating certain spacing or separation tasks to the flight crew, for example:

- Improving runway throughput in instrument meteorological conditions (IMC) through use of new cockpit tools;

RTCA Paper No. 242-11/SC186-317

- More efficient departure sequencing without increases in ATC workload;
- Enabling aircraft in oceanic airspace to fly more optimal cruise profiles and pass other aircraft on parallel routes; and
- Accommodating more kinds of flight trajectories than ATC currently authorizes.

The individual ASA applications are described in §1.3. It is a goal of these applications to minimize any increase in workload while ensuring safety. Particular attention is paid to preventing workload increases during critical phases of flight, such as final approach and landing.

Some ASA applications are independent of ground systems and air traffic control, while others depend on or interact with services provided by ground systems and air traffic control. These MASPS do specify requirements for ground systems such as Traffic Information Service – Broadcast (TIS-B) and the Automatic Dependent Surveillance – Rebroadcast (ADS-R) services, and states assumptions about the functional and performance capabilities of the services they provide to the extent that these are required by ASA applications. ADS-B is used to augment or improve current ATC ground surveillance.

1.2.2 Application Assumptions

To achieve the expected gains, this document makes certain assumptions (**ASSUMP #**) about the use of new technology, and summarizes these assumptions in §3.7.1. These assumptions are predicated on the evolution of separation responsibility for the applications covered here. These assumptions include, but are not limited to:

ASSUMP 1: Flight crews, in appropriately equipped aircraft, will be able to perform some functions currently done by ATC, some of which may be at reduced separation standards compared to current separation standards.

ASSUMP 2: The variability in the spacing between aircraft in the airport arrival and/or departure streams will be reduced with the use of certain ASA applications.

ASSUMP 3: For the near and mid-term applications, ATC will be willing to act as a "monitor" and retain separation responsibility between designated aircraft.

ASSUMP 4: Pilot and ATC workload will not be increased substantially by ASA applications.

ASSUMP 5: Most aircraft will eventually be equipped with avionics to perform ASA applications (this is necessary to maximize system benefits).

ASSUMP 6: For the far-term applications, pilots may be willing to accept additional separation responsibility beyond what they have today that is currently provided by ATC.

ASSUMP 7: ADS-B avionics and applications will be compatible with future ATC systems and operating procedures.

These assumptions have not yet been fully validated.

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1.2.3 ASA Architecture

Figure 1-1 provides an overview of the ASA system architecture and depicts the interfaces between functional elements for an ASA aircraft participant and external systems. The ASA system architecture consists of three major components: subsystems for the transmit participant, subsystems for the receive participant, and the ground systems. The ASA also interfaces with other aircraft systems.

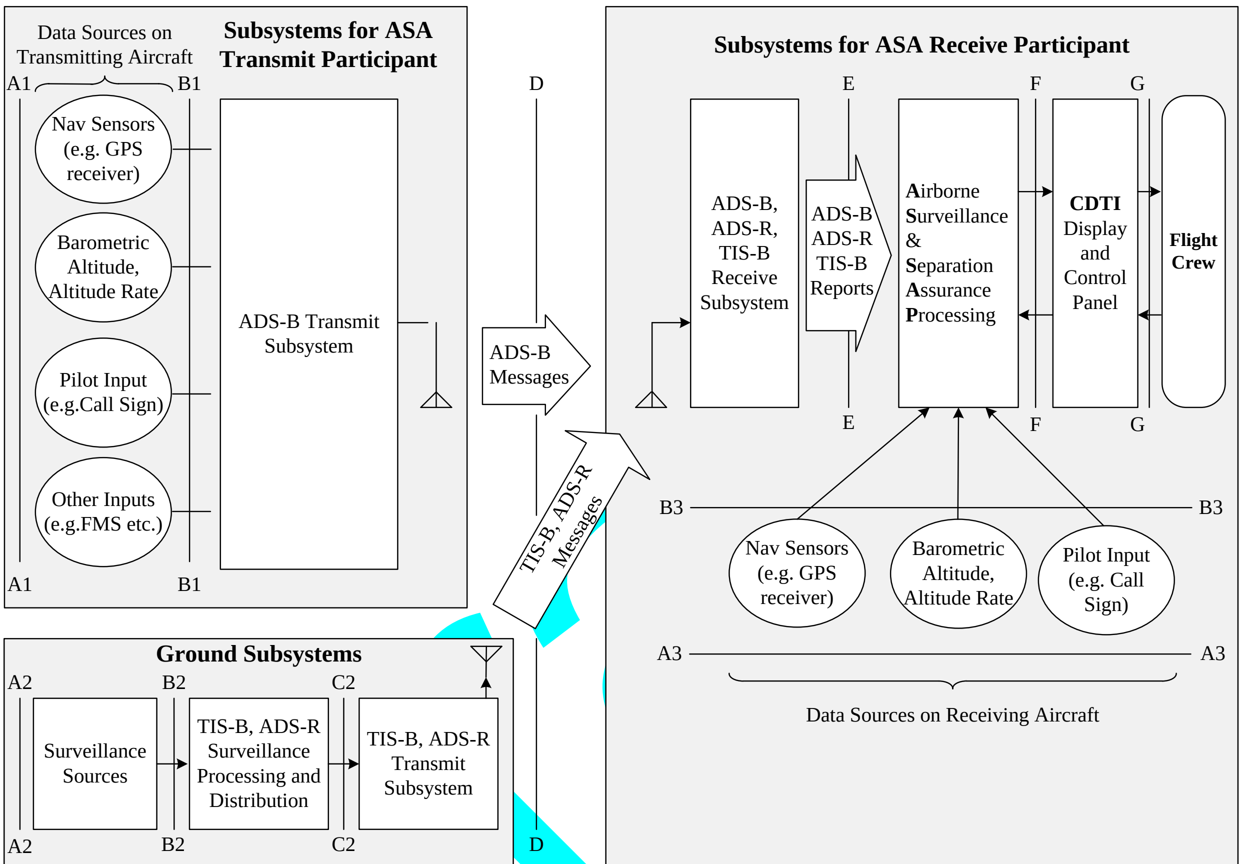

Figure 1-1: Overview of ASA Architecture

Note that there is a clear distinction in the diagram between messages and reports. An ADS-B Message is a block of formatted data that conveys the information elements used in the development of ADS-B Reports. Message content and formats are unique for each of the ADS-B data links. These MASPS do not address these message definitions and structures. An ADS-B Report contains the information elements assembled by an ADS-B receiver using message content received from ADS-B, ADS-R, and TIS-B messages from transmitting airborne and ground participants. These reports are available for use by the ASSAP and CDTI subsystems.

1.2.3.1 ASA Transmit Participant Subsystem

The subsystem for the ASA transmit participant accepts navigation and other data inputs from the aircraft, processes it to create the link unique ADS-B Messages, and then broadcasts those ADS-B Messages. The navigation data contains position and velocity information, as well as the accuracy and integrity parameters characterizing that data, either directly from a Global Navigation Satellite System (GNSS) receiver or a GNSS based navigation system. There are increasingly restrictive thresholds for the accuracy and integrity metrics of the navigation data as the system applications progress in criticality from situational awareness to separation assurance.

Other data sources include the barometric altitude and altitude rate and pilot inputs such as the flight identification. A critical performance requirement in the transmit subsystem is minimizing the latency between the time the GNSS sensor makes the position measurement and broadcasting it in the ADS-B Messages.

1.2.3.2 ASA Receive Participant Subsystem

This section will describe the subsystem from Interface “D” and “A3” to Interface “G” in Figure 1-1.

The subsystem for the ASA receive participant accepts ADS-B Message from aircraft and other vehicles, ADS-R and TIS-B Messages from the ground system, and navigation and other data inputs from the aircraft. The Messages are assembled into Reports and are processed in the supporting applications, and the applications provide relevant information to the Flight Crew. The subsystem also includes Flight Crew inputs.

1.2.3.2.1 ADS-B Receive Subsystem

The ADS-B receive subsystem, which includes the reception of ADS-R, TIS-B and FIS-B Messages, provides the receiving functionality for surveillance messages transmitted over each ADS-B data link. The ADS-B receive subsystem processes received messages and provides the corresponding ADS-B, ADS-R and TIS-B Reports to the ASSAP function. The ADS-B receive subsystem also receives TIS-B and ADS-R Service Status Messages. Users equipped with the UAT data link will also receive FIS-B Messages.

1.2.3.2.2 ASSAP Subsystem

Processing is performed by ASSAP, which takes the incoming surveillance information and processes it according to the appropriate ASA application(s) as selected by the flight crew. For example, the ASSAP may predict a violation of the applicable separation minima, and determine appropriate resolution guidance.

ASSAP is the processing subsystem that accepts surveillance reports, performs any necessary correlation and/or tracking, and performs application-specific processing. Surveillance reports, tracks, and any application-specific alerts or guidance are output by ASSAP to the CDTI subsystem. In addition to these interfaces and depending on the actual ASA application, ASSAP may interface to the Flight Management System (FMS) and/or the Flight Control (FC) systems for flight path changes, speed commands, etc.

1.2.3.2.3 CDTI Subsystem

The Cockpit Display of Traffic Information (CDTI) provides the flight crew interface to the ASA system. It displays traffic information as processed by the ASSAP. It provides other necessary information, such as alerts and warnings, and guidance information. The CDTI also provides flight crew inputs to the system, such as display preferences, application selection, and designation of specific targets and parameters for certain applications.

The CDTI subsystem includes the actual visual display media, any aural alerting and the necessary controls to interface with the flight crew. Thus, the CDTI consists of a display and a control panel. The control panel may be a dedicated CDTI control panel or it may be incorporated into another control, e.g., a multi-function control display unit (MCDU). Similarly, the CDTI display may also be a stand-alone display (dedicated display) or the CDTI information may be presented on an existing display (e.g., multi-function display).

The TCAS traffic display may be a separate display or TCAS traffic may be integrated with ASA surveillance data and presented in a combined format. If TCAS traffic is integrated with other surveillance data, only one symbol should be displayed to the flight crew for any one aircraft.

Note: *It is highly desirable that the TCAS traffic display be integrated with the CDTI.*

1.2.3.3 Ground Subsystems

1.2.3.3.1 TIS-B

Not all aircraft will be equipped to broadcast their position via ADS-B. It is anticipated that there will be a long transition period over which aircraft owners decide to equip their aircraft, and that some aircraft owners may choose never to equip. In addition, situations will occur where the ADS-B Reporting equipment on an aircraft is not operating although it is installed.

To fill this information gap, the concept of Traffic Information Service Broadcast (TIS-B) [43] was developed. Within their coverage areas, ground surveillance systems can determine the positions of transponder-equipped aircraft and broadcast this position data to ASA-equipped aircraft via TIS-B. Multi-lateration surveillance systems developed for the airport surface may provide position accuracies comparable to those from GNSS. Away from the vicinity of the airport, ground sensors (e.g., radar systems or wide area multi-lateration systems) provide the surveillance input data for TIS-B. These ground systems may provide less accuracy, but the position information should be suitable for providing situational awareness with respect to aircraft not equipped with ADS-B position reporting.

1.2.3.3.2 ADS-R

Automatic Dependent Surveillance – Rebroadcast (ADS-R) messages are crosslink translations from UAT to 1090ES and from 1090ES to UAT provided by the ground surveillance service. The ADS-R service is only provided when an aircraft in range of the broadcast antenna indicates that it has the capability to accept messages that are relayed from the UAT ADS-B link to 1090ES ADS-B link, and likewise from 1090ES to UAT equipped aircraft.

1.2.3.3.3 ADS-B Ground Receivers

The ADS-B ground system is comprised of a network of radio receivers designed to provide surveillance coverage of ADS-B Out broadcasts throughout the NAS that is equivalent or better that existing radar coverage. The ADS-B system will provide aircraft position and state data with substantially better accuracy and update rates for ATC automation systems, which provide an opportunity for reduced separation standards and more efficient flight operations.

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1.2.3.4 System Classifications

Aircraft ASA systems which include both link message transmit and receive capability are defined to be Class A systems. Systems which include only the link transmit capability are defined to be Class B systems. Subcategories within the classes define capability thresholds based on parameters such as transmit power and receiver sensitivity to align equipment capabilities with intended applications. Ground systems are defined to be Class C systems.

1.2.4 Relationship to TCAS

The Traffic Alert and Collision Avoidance System (TCAS), known internationally as the Airborne Collision Avoidance System (ACAS), provides flight crews with a traffic situation display and with safety alerts. Its success, and the attempt to use it for some additional applications for which it was not intended or well suited, helped promote interest in a more general ASA system to address those applications not directly associated with collision avoidance.

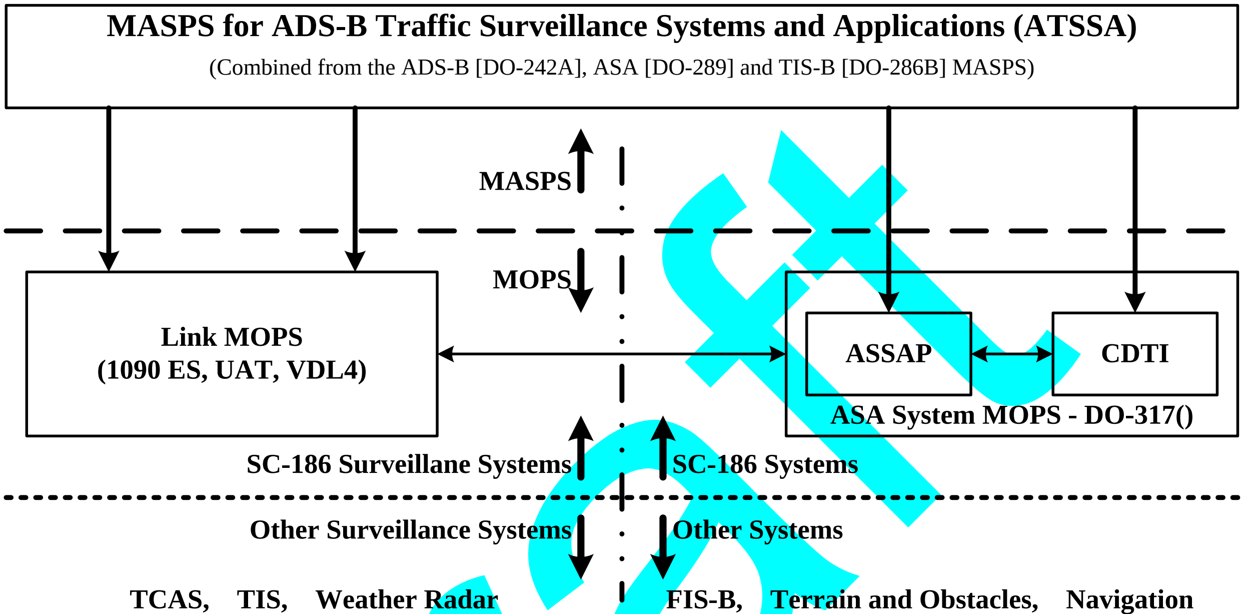
TCAS provides a backup safety system for separation assurance. On aircraft that carry both an ASA and a TCAS, the TCAS collision avoidance system must continue to function correctly when ASA fails. This need does not preclude an avionics architecture that integrates TCAS and ASA functionality in the same equipment, provided the frequency of common mode failures is sufficiently small in the context of providing collision avoidance protection when separation provision has failed. The operational uses of TCAS and ASA, and in particular their flight crew interfaces, will have to be carefully coordinated in order to ensure that all the intended safety and operational benefits are provided.

Note: *If future ASA applications are proven to provide increased safety, the interaction between ASA and TCAS may be altered; this will require validation.*

ADS-B surveillance differs from TCAS surveillance in that ADS-B broadcasts position and velocity information while TCAS derives relative position information through an interrogate – reply protocol. ADS-B covers a larger range (potentially 90 to 120 NM), and has greater overall accuracy. Altitude information in both systems is dependent upon on-board equipment. As a last-minute safety system, TCAS only needs to provide surveillance to approximately 15 NM. While TCAS measures range with great accuracy, it is unable to make highly accurate bearing measurements because of the limitations imposed by the available antenna technology that can be installed on aircraft. When GNSS is used as the navigation data source for ADS-B, highly accurate position measurements can generally be provided in all dimensions. This may allow added integrity to vertical height based only on pressure altitude. The relative position between two aircraft is calculated from these position reports, rather than measured, and the accuracy does not depend on the distance between the aircraft. The relative position will also differ from TCAS systems in allowing for relatively compact and inexpensive implementations suitable for categories of aircraft where TCAS is not required and is not economically attractive.

1.2.5 Relationship to RTCA / EUROCAE and Other Documents

The diagram in Figure 1-2 shows the relationships between these MASPS, the Aircraft Separation Assurance (ASA) MASPS [49] and other RTCA SC-186 documents, such as the Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) MASPS [27] and the various link Minimum Operational Performance Standards (MOPS) [37, 42].



<u>Figure 1-2:</u> Relationship Between These MASPS and Other RTCA Documents

Two RTCA ADS-B Link MOPS have been identified: 1090 MHz Extended Squitter ADS-B (1090ES) [37] and Universal Access Transceiver (UAT) [42]. The 1090ES MOPS has been revised and issued as RTCA DO-260B, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services (TIS-B)*. The UAT MOPS has recently been revised and issued as RTCA DO-282B, *Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast (ADS-B)*. EUROCAE Working Group 51 has issued EUROCAE ED-108A [4], an updated MOPS for VDL Mode 4, and a third ADS-B link. Additionally, EUROCAE Working Group 51 has released EUROCAE ED-102A, which is identical to RTCA DO-260B.

<u>Note:</u> *The VDL-4 ADS-B Link MOPS is a EUROCAE document, not an RTCA document.*

The Airborne Surveillance and Separation Assurance Processing (ASSAP) and the Cockpit Display of Traffic Information (CDTI) subsystems are closely related items and are written as a joint MOPS in RTCA DO-317A, *Airborne Surveillance Application (ASA) System MOPS* [49].

Figure 1-2 also shows the functions under the auspices of RTCA SC-186 and those systems outside the scope of RTCA SC-186. These MASPS make requirements allocations to the functions under the auspices of RTCA SC-186 and makes assumptions on the systems outside the scope of RTCA SC-186.

Surveillance Systems that are outside of the scope of RTCA SC-186 are the TCAS, Traffic Information Service (TIS), weather radar, and Flight Information Service – Broadcast (FIS-B). Terrain systems, e.g., Terrain Awareness and Warning System (TAWS) and Navigation systems, e.g., GNSS, are also outside the scope of RTCA SC-186.

The ADS-B In applications may be identified by the terminology used in the current version of the FAA Application Integrated Work Plan (AIWP) Version 2 document [10]. See Appendix A for all of the various names that this includes.

1.3 Operational Application(s)

The situational awareness and separation assurance capabilities of ASA are provided by applications. Numerous applications have been proposed, and it is expected that additional applications will be developed and standardized in future versions of these MASPS. The applications fall into five broad categories: situational awareness, extended situational awareness, spacing, delegated separation, and self-separation.

Situational awareness applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changes in separation tasks or responsibility are required for these applications.

Extended situational applications add provisions such as cueing to the pilot through indications and alerts, or providing a new separation standard during the procedure.

Spacing applications require flight crews to achieve and maintain a given spacing with designated aircraft, as specified in a new ATC instruction. Although the flight crews are given new tasks, separation provision is still the controller's responsibility and applicable separation minima are unchanged.

In delegated separation applications, the controller delegates separation responsibility and transfers the corresponding separation tasks to the flight crew, who ensures that the applicable airborne separation minima are met. The separation responsibility delegated to the flight crew is limited to designated aircraft, specified by a new clearance, and is limited in time, space, and scope. Except in these specific circumstances, separation provision is still the controller's responsibility. These applications will require the definition of airborne separation standards.

Self separation applications require flight crews to separate their flight from all surrounding traffic, in accordance with the applicable airborne separation minima and rules of flight.

1.3.1 Initial Applications

This document specifies detailed requirements for an initial set of applications. EVAcq defines the requirements ASA systems must meet to provide ADS-B basic traffic situational awareness. The AIRB application defines the requirements ASA systems must meet to provide basic traffic situational awareness as well as provides a foundation for additional applications. The remaining applications (SURF, VSA and ITP) are optional.

1.3.1.1 Enhanced Visual Acquisition (EVAcq)

The Enhanced Visual Acquisition (EVAcq), application represents the most basic of ASA applications, and use of the CDTI. The CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window. This application is expected to improve both safety and efficiency by providing the flight crew enhanced traffic awareness. Refer to RTCA DO-289 [44] for a complete EVAcq description.

1.3.1.2 AIRB

The Basic Airborne Situational Awareness (AIRB), application extends the EVAcq application by adding the Flight ID and ground speed of selected traffic that are added to the CDTI. The CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window and provides traffic situational awareness beyond visual range. Refer to RTCA DO-319/EUROCAE ED-164 [51] for description of the AIRB application.

1.3.1.3 Visual Separation on Approach (VSA)

The Visual Separation on Approach (VSA), application is an extension of the current visual approach procedure. The CDTI is used to assist the flight crew in acquiring and maintaining visual contact during visual separation on approach. The CDTI is also used in conjunction with visual, out-the-window contact to follow the preceding aircraft during the approach. The application is expected to improve both the safety and the performance of visual separation on approach. It may allow for the continuation of visual separation on approach when they otherwise would have to be suspended because of the difficulty of visually acquiring and tracking the other preceding aircraft. Refer to RTCA DO-314/EUROCAE ED-160 [48] for a complete VSA description.

1.3.1.4 Basic Surface Situational Awareness (SURF)

The Basic Surface Situational Awareness (SURF), application is to provide the flight crew with Ownship positional and traffic situational awareness information relative to an airport map. The CDTI includes an airport surface map underlay, and is used to support the flight crew in making decisions about taxiing, takeoff and landing. This application is expected to increase efficiency of operations on the airport surface and reduce the possibility of runway incursions and collisions. Refer to RTCA DO-322/EUROCAE ED-165 [53] for a description of the SURF application.

1.3.1.5 Oceanic In-Trail Procedures (ITP)

In-Trail Procedures (ITP) in Oceanic Air Space enables aircraft that desire flight level changes in procedural airspace to achieve these changes on a more frequent basis, thus improving flight efficiency and safety. The ITP achieves this objective by permitting a climb-through or descend-through maneuver between properly equipped aircraft, using a new distance-based longitudinal separation minimum during the maneuver. The ITP requires the flight crew to use information derived on the aircraft to determine if the initiation criteria required for an ITP are met. Refer to RTCA DO-312/EUROCAE ED-159 [47] for a complete ITP description.

1.3.2 Emerging Applications

This document specifies detailed requirements for an initial set of applications.

1.3.2.1 Airport Surface Situational Awareness with Indications and Alerts (SURF IA)

Airport Surface Situational Awareness with Indications and Alerts (SURF IA) is a flight-deck based application that adds to the Airport Traffic Situation Awareness application by graphically highlighting traffic or runways on the airport map to inform flight crew of detected conditions which may require their attention. For detected non-normal – alert level – situations, which require immediate flight crew awareness, additional attention getting cues are provided. Refer to RTCA DO-323 [54] for a more complete description of SURF IA.

1.3.2.2 Traffic Situational Awareness with Alerts (TSAA)

Traffic Situational Awareness with Alerts (TSAA) will provide traffic advisories in the near term by using the CDTI and alerts to assist the pilot or flight crew with visual acquisition and avoidance of traffic in both Visual Meteorological Conditions and Instrument Meteorological Conditions. The application is applicable under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). It builds on the Basic Traffic Situational Awareness application by providing the pilot or flight crew with alerts for conflicting traffic that may or may not have been pointed out by ATC. This alert is for detected airborne conflicts.

1.3.2.3 Flight-Deck Based Interval Management-Spacing (FIM-S)

Flight-Deck Based Interval Management-Spacing (FIM-S) is a suite of functional capabilities that can be combined to produce operational applications to achieve or maintain an interval or spacing from a target aircraft. ATC will be provided with a new set of (voice or datalink) instructions directing, for example, that the flight crew establish and maintain a given time from a reference aircraft.

1.4 System Scope and Definition of Terms

The ASA system scope is all of the elements depicted in Figure 1-1. It should be noted that the transmit subsystem shown in Figure 1-1 can be implemented in either the airborne segment (ADS-B Out) or in a ground segment, as for the TIS-B or ADS-R subsystems.

The ADS-B system scope is the middle three elements shown in Figure 1-1, including: the Transmit subsystem, the broadcast link RF medium, and the Receive & Report Generation function.

The list of acronyms and definitions of terms are included in Appendix A.

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2 Operational Requirements

2.1 General Requirements

ADS-B is designed to support numerous applications. Many of these applications are described in this Section and in the Appendices.

Since the initial publication of this document, many of the ADS-B Out and ADS-B In applications have undergone a rigorous development of their operational and performance requirements which have been published in other RTCA documents. The high level performance requirements for the ADS-B In applications are summarized in Table 2-3. The high level performance requirements for the ADS-B Out applications are summarized in Table 2-7.

This section describes the operational performance requirements for the existing applications and a candidate set of potential future ADS-B applications. A candidate number of scenarios are defined that identify conditions that are driving factors in deriving full capability ADS-B system-wide functional and performance requirements. This candidate set should not be interpreted as a minimum or maximum for a given implementation. Furthermore, all implementations are not required to support all applications.

The following key terms are used within this section.

- **ADS-B Message.** An ADS-B Message is a block of data that is formatted and transmitted that conveys the information elements used in the development of ADS-B Reports. Message contents and formats are specific to each of the ADS-B data links; these MASPS do not address message definitions and structures.

- **ADS-B Report.** An ADS-B Report contains the information elements assembled by an ADS-B receiver using messages received from a transmitting participant. These information elements are available for use by applications external to the ADS-B system.

2.1.1 General Performance

2.1.1.1 Consistent Quantization of Data

When the full resolution of available aircraft data cannot be accommodated within an ADS-B Message, a common quantization algorithm **shall (R2.001)** {from 242AR2.1} be used to ensure consistent performance across different implementations. To minimize uncertainty, a standard algorithm for rounding/truncation is required for all parameters. For example, if one system rounds altitude to the nearest 100 feet and another truncates, then the same measured altitude could be reported as different values.

Unless otherwise specified, whenever more bits of resolution are available from the data source than in the data field into which that data is to be loaded, the data **shall (R2.002)** {new reqmt} be rounded to the nearest value that can be encoded in that data field.

Notes:

1. *Unless otherwise specified, it is accepted that the data source may have less bits of resolution than the data field.*

2. *Users of the ADS-B Message formats should perform a comparison between the quality metrics applied and the resolution of each message element that those metrics are applied against. There are some combinations of message data elements and quality metrics that are not compatible. For example, in the 1090 MHz Extended Squitter system, the application of a NAC_V = 4 (Velocity accuracy < 0.3 m/s) requirement to the Airborne Velocity Message (Register 09_{16}) Subtypes 1 or 3 (subsonic), which has a minimum resolution of only 1 knot (~0.5 m/s). Another example would be the application of a NAC_V = 3 (Velocity accuracy < 1 m/s) or NAC_V = 4 requirement to the Airborne Velocity Message Subtypes 2 or 4 (supersonic), which have a minimum resolution of 4 knots (~2 m/s).*

2.1.1.2 ADS-B Reports Characteristics

The output reports of the ADS-B Receive Subsystem **shall (R2.003)** {from 242AR2.2} be generated with sufficient resolution so they can be conveyed without compromising accuracy of any received data. The ADS-B Reports should support surface and airborne applications anywhere around the globe and should support chock-to-chock operations without the need for pilot adjustments or calibrations.

2.1.1.3 Expandability

Applications envisioned for using the information provided by ADS-B are not fully developed. In addition, the potential for future applications to need information from an ADS-B system is considered fairly high. Therefore the ADS-B system defined to meet the requirements in these MASPS needs to be flexible and expandable. Any broadcast technique should have excess capacity to accommodate increases and changes in message structure, message length, message type and update rates.

Note: *The update rate is the effective received update rate as measured at the receiving end system application (e.g., the automation system interface by ADS ground processing), not the transmission rate of the ADS-B system.*

These MASPS identifies different report parameters with different update rates. In some cases the resolution of the parameters may be different depending on the intended use. Ideally, the system should be designed so that message type, message structures, and report update rates can be changed and adapted by system upgrades.

2.2 System Performance – Standard Operational Conditions

2.2.1 ADS-B System-Level Performance

The standard operating conditions for ADS-B are determined by the operational needs of the target applications listed in Table 2-1. System performance requirements and needs for ADS-B are provided in terms of the operational environments and the information needs of applications making use of ADS-B information in those environments.

The following subsections describe representative scenarios used to derive ADS-B system-wide functional and performance requirements.

Application scenarios are grouped according to whether the user is operating an aircraft/ vehicle (ADS-B In) or is an Air Traffic Services provider (ADS-B Out). These scenarios outline the operational needs in terms of the information required, such as its timeliness, integrity, or accuracy. The intent for these is to meet the requirements in a manner which is independent of the technology which provides the underlying needs. Information timeliness, for example, may be provided either through a higher transmission rate or through a transmission environment that has a higher message delivery success rate.

A high level assessment of operational considerations for each airborne ADS-B In application category is summarized in Table 2-1. The top level traffic ("targets") performance requirements for the existing ADS-B In applications compared to the minimum performance levels for each category of ADS-B transmit sources (i.e., ADS-B [direct air to air], ADS-R and TIS-B) are presented in Table 2-3. The airborne source's performance levels are from the FAA Final ADS-B Out Rule and Advisory Circular AC 20-165 [6]. The TIS-B and ADS-R performance levels are taken from the latest version of the FAA SBS Description Document [11].

A summary of the broadcast information provided by ADS-B and its applicability to the target applications is provided in Table 2-2. Assumptions for A/V-to-A/V scenarios are summarized in Table 2-4. A summary of ATS provider surveillance and conflict management current capabilities for sample scenarios is provided in Table 2-5. Additional and refined capabilities appropriate for ADS-B are provided in Table 2-6. Note that earlier versions of the ADS-B MASPS documents used the term "Station-Keeping" to describe a category of ADS-B In applications. Those applications are now categorized as "Spacing Applications" in this version. Also previous versions used the term "Cooperative Separation" to describe an advanced category of ADS-B In applications. That category is now designated as "Delegated Separation" applications in this document. Similarly, the "Flight Path Deconfliction Planning" function is now assumed to be part of the "Delegated Separation and Self Separation" applications.

Note: *Table entries not containing references supporting the value specified are based on operational judgment and may need further validation in future versions of these MASPS.*

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Table 2-1: High Level Considerations for ADS-B In Applications by Category

	1 SA Applications			2 "Extended SA" Applications			3 Spacing Apps		4 Delegated Separation Applications				5 Self Separation	
	Airborne	Approach	Surface	Oceanic	Approach	Surface	EnRoute / Terminal		EnRoute / Terminal				EnRoute / Terminal	
Requirement	**EVAcq/AIRB**	**VSA**	**SURF**	**ITP**	**CAVS/ CEDS**	**SURF IA**	**FIM-S**	**Advanced**	**FIM-DS**	**DS-C/P**	**ICSPA**	**DSWRM**	**FC**	**Self Sep**
Separation Responsibility	ATC [1]	ATC [1, 2]	ATC [1]	ATC	ATC	ATC	ATC	ATC	Shared	Shared	Shared	Shared	Aircraft	Aircraft
100% OUT Equipage? (Direct, ADS-R or TIS-B)	No	No	No	No	No	No	No	No	TBD	TBD	TBD	TBD	TBD	TBD
100% IN / CDTI Equipage?	No	No	No	No	No	No	No	No	TBD	TBD	TBD	TBD	TBD	TBD
Operational Conditions	TBD	VMC Only	No Reqmt	VMC / IMC	VMC / IMC	No Reqmt	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC	VMC / IMC
3D / 4D Intent Data?	No	No	No	No	No	No	TBD	TBD	TBD	TBD	TBD	TBD	Yes	Yes
Wake Vortex Data?	No	No	No	No	No	No	No	No	No	TBD	TBD	Yes	TBD	TBD
Increased Performance Levels? [3] (> FAA 2020 Mandate)	No	No	Yes	No	TBD	Yes	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Ownship Interaction with Target Aircraft	Receive Only	Designate	Receive Only	Designate	Designate	Receive Only	Designate	Designate	Designate	Designate	Designate	Designate	TBD	TBD

Notes:

1. *Only when aircraft is on IFR Flight Plan.*
2. *ATC for all aircraft except ATC designated traffic to follow.*
3. *Performance level used for comparison is that of FAA Final ADS-B OUT Rule and FAA AC 20-165 [6].*
4. *Red highlighting means that there may be a problem meeting the minimum performance requirements of the application.*
5. *Yellow highlighting means that the requirements are not defined.*

1253

1254 **Table 2-2: Required Information Elements to Support Selected ADS-B Applications**

Information Element ↓	Airborne Situational Awareness (EVAcq/ AIRB)	Extended Situational Awareness (ITP)	Spacing (FIM-S)	Delegated Separation Assurance & Sequencing (FIM-DS)	Simultaneous Approaches (DS)	Airport Surface (A/V to A/V & A/V to ATS)	Self Separation	ATS Surveillance ADS-B OUT	Traffic Situation Awareness W/Alerts (TSAA)	Notes
Identification										
Flight ID (Call Sign)		•	•	•	•	•	•	•		1
Address	•	•	•	•	•	•	•	•	•	
Category				•	•	•	•	•		
Mode A Code								•		
State Vector										
Horizontal Position	•	•	•	•	•	•	•	•	•	
Vertical Position	•	•	•	•	•		•	•	•	
Horizontal Velocity	•	•	•	•	•		•	•	•	
Vertical Velocity	•	•	•	•	•		•	•	•	
Surface Heading						•				
Ground Speed						•				
NIC		•	•	•	•	•	•	•	•	
Mode Status										
Emergency/ Priority Status	•	•	•					•		
Capability Codes		•	•	•	•	•	•	•	•	
Operational Modes		•	•	•	•	•	•	•	•	
NAC_P	•	•	•	•	•	•	•	•	•	
NAC_V		•	•	•	•	•	•	•	•	
SIL		•	•	•	•	•	•	•	•	
SDA	•	•	•	•	•	•	•	•	•	
ARV				**TBD**						
Intent Data (Note 1)				**TBD**			**TBD**		**TBD**	

1255 ***Notes for Table 2-2:***

1256 • = *Expected Application Requirement*

1257 1. *ADS-B is one potential means to provide intent information to support ATS. Other alternatives, not involving ADS-B, may become available.*

1258

Table 2-3: ADS-B Transmit Sources – Minimum Required Performance vs ADS-B In Application Requirements

		1 SA Applications			2 "Extended SA" Applications			3 Spacing Applications		4 Delegated Separation Applications				5 Self Separation	
		Airborne	Approach	Surface	Oceanic	Approach	Surface	EnRoute / Terminal		EnRoute / Terminal				EnRoute / Terminal	
		EVAcq/AIRB	VSA	SURF	ITP	CAVS	SURF IA	FIM-S		FIM-DS	ICSPA	DS-C/P	DSWRM	FC	Self Sep
TRANSMIT SOURCES		DO-317A	DO-317A	DO-317A	DO-317A	CEDS	DO-323	DO-328			DO-289 Apndx J				
A. Airborne Platforms															
Accuracy (NAC_P)	8	5	6	7 / 9 [5]	5	TBD	9 / 10 / 11	6 / 7			9				
Integrity (NIC)	7	N / A	6	N / A	5	TBD	N / A	5 / 7			9				
Vel Acc (NAC_V)	1	1	1	2	1	TBD	1	1			3				
Src Integ Lvl (SIL)	3	N / A	1	N / A	2	TBD	2	2			2				
Sys Design Assur (SDA)	2	1	1	1 / 2 [3]	2	TBD	2	2			TBD				
Flight ID	Yes	N / A	Required	N / A	Required	TBD	N / A	Required			Required				
B. Ground Segment: ADS-R															
Accuracy (NAC_P)	9 max	5	6	7 / 9 [5]	N / A	TBD	9 / 10 / 11	6 / 7			9				
Integrity (NIC)	8 max	N / A	6	N / A	N / A	TBD	N / A	5 / 7			9				
Vel Acc (NAC_V)	1	1	1	2	N / A	TBD	1	1			3				
Src Integ Lvl (SIL)	3	N / A	1	N / A	N / A	TBD	2	2			2				
Sys Design Assur (SDA)	2	1	1	1 / 2 [3]	N / A	TBD	2	2			TBD				
Flight ID	Yes	N / A	Required	N / A	N / A	TBD	N / A	Required			Required				
C. Ground Segment: TIS-B		TIS-B as currently implemented was not intended to support these applications.													
Accuracy (NAC_P)	5 / 6 / 9 [2]	5	6	7 / 9 [5]	N / A	TBD	9 / 10 / 11	6 / 7			9				
Integrity (NIC)	0	N / A	6	N / A	N / A	TBD	N / A	5 / 7			9				
Vel Acc (NAC_V)	0	1	1	2	N / A	TBD	1	1			3				
Src Integ Lvl (SIL)	2 [4]	N / A	1	N / A	N / A	TBD	2	2			2				
Sys Design Assur (SDA)	2 [4]	1	1	1 / 2 [3]	N / A	TBD	2	2			TBD				
Flight ID	No	N / A	Required	N / A	N / A	TBD	N / A	Required			Required				

Legend: *Green = Source meets application's requirements*
Red = Source does not meet application's requirements
Yellow = Source does not meet application's requirements but one or more mitigation methods are available.

__Notes for Table 2-3:__

1. *The airborne source's performance levels (in Group A) are from the FAA Final ADS-B Out Rule and Advisory Circular AC 20-165 [6]. The ADS-R (in Group B) and TIS-B (in Group C) performance levels are from the latest version of the FAA SBS Program Office Description Document, SRT-047, Revision 01 [11].*
2. *TIS-B NAC_P values for the En Route & Terminal Environments are ≥5. TIS-B NAC_P values are for airborne (6) & surface (9) targets in the Surface Environment.*
3. *FAA TSO-C195 [13] states applications' Hazard Level for ownship when airborne or on surface > 80 knots = Major (SDA=2), Hazard Level for ownship < 80 knots = Minor (SDA=1).*
4. *TIS-B Service does not broadcast a SDA or SIL value, but the SBS Air ICD defines TIS-B service SDA and SIL equivalent to 2.*
5. *SURF surface targets require $NAC_P \geq 9$, SURF airborne targets require NAC_P = 7 or 9 depending on parallel runway spacing.*

Table 2-4: Summary of A/V-to-A/V Performance Assumptions for Support of Indicated Applications

	Operational Capability							
Information ↓	**Airborne Situational Awareness**	**Extended Situational Awareness**	**Conflict Avoidance and Collision Avoidance**	**Terminal Spacing**	**Separation Assurance and Sequencing**		**Simultaneous Approach**	**Airport Surface Situational Awareness (Note 4)**
	EVAcq/ AIRB	**ITP**	**Integrated Collision Avoidance**	**FIM-S**	**Delegated Separation FIM-DS**	**Delegated Separation in Oceanic/ Low Density En route**	**Delegated Separation CSPA, ICSPA**	
Initial Acquisition of Required Information Elements (NM)	10		20	20	40 (50 desired) (Note 6 & 8)	90 (120 desired) (Note 6)	10	5
Operational Traffic Densities # A/V (within range) (Note 3)	21 (< 10 NM)		24 (< 5 NM); 80 (< 10 NM); 250 (< 20 NM)	6 (< 20 NM)	120 (< 40 NM)	30 (< 90 NM)	32 landing; 3 outside extended runway; 5 beyond runway	25 within 500 ft 150 within 5 NM
Service Availability % (Note 4)	95		99.9	99.9	99.9	99.9	99.9	99.9

Notes for Table 2-4:

1. *System must support all traffic in line of sight that have operational significance for the associated applications (i.e., within operationally relevant ranges and altitudes for these applications). The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation. (Refer to Table TBD for requirements which are based on operational traffic densities derived from the Los Angeles basin model).*
2. *Service availability includes any other systems providing additional sources of surveillance information.*
3. *Initial acquisition of intent information is also required at this range.*
4. *This includes inappropriate runway occupancy at non-towered airports.*
5. *The operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

2.2.1.1 ADS-B System-Level Performance - Aircraft Needs

The following scenarios focus on aircraft systems and applications that use surveillance information pertaining to other aircraft within operationally relevant geometries and ranges. These scenarios assume that participating aircraft are CDTI equipped, with appropriate features, to assist in these operations. However, this does not imply that CDTI is required for these applications. Detailed traffic display requirements are provided in the appropriate application MOPS. Air-to-air capabilities enabled by ADS-B equipage classes are depicted in Figure 2-3.

Note: *For aircraft (targets) that will support higher integrity categories of ADS-B In applications such as spacing or delegated separation, a capability to independently validate the ADS-B surveillance information is likely to be required [6]. Alternative validation means are under study. An example of this independent validation would be the possible use of TCAS ranging data to validate the received Version 0 and 1 ADS-B Position Messages, which is required in RTCA DO-317A [49] for the In Trail Procedure (ITP). Application developers should note the useful range of TCAS for this function is well below the effective range of the higher ADS-B classes such as A3. Validation is available for UAT users with Passive Ranging.*

2.2.1.1.1 Aircraft Needs While Performing Airborne Situational Awareness [EVAcq/AIRB]

Transmission, air-to-air reception, and cockpit display of ADS-B information enables the Airborne Situational Awareness CDTI application (EVAcq/AIRB). This scenario is applicable in all airspace domains when ownship is airborne.

Environment

The following are the assumptions (**ASSUMP #8**) about the operational environment for the AIRB application:

- The AIRB application can be used by aircraft operating in any airspace class (i.e., A thru G).

- The AIRB application can be used by aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR).
- The AIRB application can be used under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).
- The AIRB application can be used in airspace of any traffic density.
- The ADS-B equipage (i.e., ADS-B Out and ADS-B In) within the deployment environment will be partial.
- The AIRB application does not change the roles or responsibilities for controllers in comparison with existing operations.
- The AIRB application may be used in regions where only radar surveillance is utilized and can also be used in regions where ADS-B Out ATS surveillance is utilized.

<u>Operational Scenario</u>

The AIRB application includes two phases:

- “Enhanced traffic situational awareness” – the flight crew scans the CDTI to identify any traffic of interest, correlates the CDTI data with any other available sources of information (out-the-window and/or radio communication) to check consistency, collects missing information if necessary and assesses the traffic situation based on all available information. The flight crew can also look at the CDTI to try to identify if a known traffic (e.g., following visual acquisition or traffic information from the controller) is displayed. Then, they correlate the various sources of information for this specific traffic.
- “Enhanced flight operations” – After building this enhanced traffic awareness, the flight crew uses this information to operate the aircraft as in existing operations (according to the current flight rules and class of airspace) but with having an improved knowledge of their local traffic situation.

As an example, these phases correspond to the two tasks of the “see-and-avoid” procedure. The first action (“see”) consists in achieving visual acquisition on another aircraft and in determining whether this aircraft is a threat. With the AIRB application, the flight crew will be supported by the CDTI in addition to the out-the-window information to determine whether an avoiding maneuver is needed. Then, the second action (“avoid”) consists of maneuvering safely to avoid this threat. With the AIRB application, the flight crew will be supported by the CDTI in addition to the out-the-window information to better assess the traffic situation while maneuvering.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support the aid to visual acquisition.

2.2.1.1.2 Aircraft Needs for Approach Applications – Enhanced Visual Approach [VSA]

The enhanced visual approach (VSA) application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft. The CDTI may also be used to monitor traffic on a parallel approach. This application is expected to improve the safety as well as the routine performance of visual approaches.

<u>Environment</u>

The following are the assumptions (**ASSUMP 9**) about the operational environment for the VSA application:

- The VSA application can be used by aircraft flying a visual or an instrument approach.
- The VSA application is applicable to single runway, independent parallel runways, dependent parallel runways, and closely-spaced parallel runways.
- The VSA application can only be conducted under VMC as defined by ICAO or as specified by the State.
- The VSA application can be used by all suitably equipped aircraft during approach to any airports where own visual separation is used.
- The airspace in which the VSA application is used has VHF voice as the means of communication between the controllers and flight crews.
- The VSA application can be applied in airspace of any traffic density.
- The minimum spacing between the preceding aircraft and succeeding aircraft during the Visual Acquisition phase is 3 NM.
- At a range of 5 NM, the 95% update interval for both horizontal position and horizontal velocity is assumed to be 3 seconds.
- The ADS-B equipage (i.e., ADS-B Out and ADS-B In) within the deployment environment will be partial.

<u>Operational Scenario</u>

The current own visual separation procedure is comprised of four successive phases:

1) Visual Acquisition;
2) Clearance for Maintaining Own Visual Separation;
3) Maintaining Own Visual Separation on the Approach; and
4) Termination.

(1) **Visual Acquisition Phase**

The objective of this phase is that, at the end:

- the flight crew of the Succeeding Aircraft has:
  - detected the Preceding Aircraft on the CDTI;
  - visually acquired the Preceding Aircraft and visual contact can be maintained;
  - checked consistency of the CDTI, out the window and controller information; and
  - reported visual contact on the Preceding Aircraft to the controller;
- the controller has assessed the applicability of providing a clearance for maintaining own visual separation.

This phase includes two procedures.

- The "Basic Procedure" is based on current ATC procedures. Flight crew's procedures are only changed to include the use of the CDTI.
- The "Advanced Procedure" defines, in addition, new procedures for both the controller and the flight crew of the Succeeding Aircraft related to the use of the aircraft identification of the Preceding Aircraft by the flight crew using a modified phraseology.

(2) **Clearance Phase**

After the flight crew of the Succeeding Aircraft has explicitly reported having the Preceding Aircraft in sight, the controller provides the flight crew with the clearance to maintain own visual separation from the Preceding Aircraft. The flight crew decides to either accept or refuse this clearance and reports the decision to the controller. If the clearance is accepted, the VSA application moves to the maintaining phase. If it is not, the controller continues to provide separation to the Succeeding Aircraft by issuing clearances and instructions.

(3) **Maintaining Own Visual Separation Phase**

In this phase, the responsibility of the flight crew is to maintain own visual separation from the Preceding Aircraft. In addition to the out the window information, the flight crew of the Succeeding Aircraft also uses the information provided by the Traffic Display to perform this task. In particular, the distance and speed information provided by the CDTI allows respectively for a better evaluation of the actual distance from the Preceding Aircraft and for an earlier detection of speed variations. The VSA application modifies the decision process (e.g., the flight crew of the Succeeding Aircraft can decide that a speed reduction is required due to an excessive speed difference detected on the CDTI but that is not yet detectable visually) but it does not change the maneuver: any maneuver **shall (R2.004)** be undertaken with visual reference to the Preceding Aircraft. The procedure in case of abnormal modes is identical to the current visual procedure (i.e., without the support of the CDTI).

(4) **Termination Phase**

In nominal conditions, the clearance for own visual separation ends when the Preceding Aircraft lands.

Note: *Under specific circumstances (e.g., under FAA procedures), the application ends when the Preceding Aircraft clears the runway.*

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support the enhanced visual approach applications.

2.2.1.1.3 Aircraft Needs for Extended Situational Awareness Applications [CAVS, CEDS, ITP]

Extended Situational Awareness application versions (CAVS or CEDS) have been developed to reduce the minimum weather conditions during which "visual" approaches can be maintained after the initial visual acquisition of the target or lead aircraft has been established.

The enhanced category of SA applications also includes the In Trail Procedures (ITP) application which provides flight crews with improved opportunities to attain their optimal flight profile on long range flights over oceanic airspace. The application allows ITP equipped aircraft a reduced separation standard during the ITP climb or descent as compared to un-equipped aircraft. Thus they can achieve a higher percentage of successful (accepted) requests from ATC for climbs or descents to their optimal flight level during each phase of the flight.

Environment

This application is utilized in oceanic airspace in either an organized track system such as PACOTS (Pacific Organized Track System) or in User Preferred Routes (UPR) airspace.

Aircraft in procedural airspace frequently fly in close proximity to other aircraft traveling along the Same Track but separated vertically. These similar ground paths may be published routes (or tracks) with identical ground paths for each aircraft, or user preferred routes with similar ground paths over a portion of the flight. Safe separation is maintained procedurally.

Frequently, operational efficiency or safety could be enhanced by climbing or descending, but the current procedural separation minima preclude the aircraft's climbing or descending through the adjacent Flight Level. In this situation, the aircraft desiring the Flight Level change would be blocked from making the climb or descent to the desired level by aircraft at an Intermediate Flight Level.

Operational and safety benefits could be achieved by enabling more Flight Level changes in these blocked situations. With a new procedure and appropriate equipment, aircraft may be allowed to change Flight Levels more frequently. Automatic Dependent Surveillance-Broadcast (ADS-B) data and onboard equipment can enable Flight Level changes in procedural airspace using procedures similar to other standard, distance based procedures. Distance-based longitudinal separation minima for climbs and descents have

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been established in procedural airspace, using information supplied by the crew to the controller for the determination of along-track distance.

The objective of the In-Trail Procedure is to enable aircraft that desire Flight Level changes in procedural airspace to achieve these changes on a more frequent basis, thus improving flight efficiency and safety. When ITP Criteria are met, the ITP achieves this objective by permitting a climb-through or descend-through maneuver past a Potentially Blocking Aircraft, using a new longitudinal separation minimum during the ITP, where this new distance-based longitudinal separation minimum is less than current longitudinal separation minima.

The In-Trail Procedure (ITP) makes climbs and descents through normally blocked Flight Levels possible, providing a safe and practical method for Air Traffic Service Providers to approve, and flight crews to conduct, such operations. The ITP would require the flight crew to use information derived on the aircraft to determine if the criteria required for making an ITP request and subsequently beginning the procedure are met. The aircraft-derived information includes Aircraft ID, Flight Level, Same Direction, ITP Distance, and Ground Speed Differential (all relative to Potentially Blocking Aircraft). The ITP Speed/Distance Criteria are designed such that the estimated positions between the ITP Aircraft and Reference Aircraft should get no closer than the ITP Separation Minimum during the portion of the climb or descent where vertical separation does not exist. ATC would verify that the ITP and Reference Aircraft were Same Track and that the maximum Positive Mach Differential was not exceeded. Once these criteria are met, and the controller determines that standard separation minima will be met with all Other Aircraft, the Flight Level change request may be granted. The ITP is comprised of a set of six different Flight Level change geometries with the specific geometry dictated by whether the ITP Aircraft desires to climb or descend and its proximate relationship with Potentially Blocking Aircraft.

The ITP is an Airborne Traffic Situational Awareness (ATSAW) application. It does not change the responsibilities of either pilots or controllers; the flight crew continues to be responsible for the operation of the aircraft and conformance to its clearance, and the controller continues to be responsible for separation and the issuance of clearances. The ITP does include new tasks for the flight crew in determining that the ITP Criteria are met. The ITP does not require the crew to monitor or maintain spacing to any aircraft during the ITP maneuver. The safety of the ITP is attained by the initial conditions which include the ITP Distance, Ground Speed Differential, vertical speed, and the vertical distance for the Flight Level change. Once it is begun, safety is assured by the crew's compliance with the Flight Level change clearance.

<u>Operational Scenario</u>

Traffic levels in procedural (e.g., oceanic) airspace are increasing. In an organized track system, some Flight Levels on a track may be loaded upon track entry with longitudinal separations at or near the separation minimum, while other Flight Levels have gaps between traffic that far exceed this minimum separation. Even in airspace with user preferred routes (UPRs), traffic situations exist where the longitudinal spacing between the only two aircraft in the immediate vicinity is less than the applicable procedural separation minimum.

An aircraft originally cleared to its initial optimum cruising Flight Level will burn sufficient fuel after several hours to justify climbing 2000 feet or more to a new optimum cruising Flight Level. More favorable winds at higher Flight Levels may also create a desire for climbs of 2000 to 4000 feet. Flight crews may also desire lower Flight Levels, perhaps to avoid turbulence or when winds are more favorable at the lower Flight Levels.

Often, when an aircraft desires a Flight Level change, this change may be blocked by another aircraft. The ITP is designed to address situations where this blocking aircraft is at a same-direction Flight Level (from 1000 to 3000 feet higher or lower) and is also less than the current longitudinal separation minimum ahead of or behind the aircraft desiring to make the Flight Level change. In this situation, the controller would be required to deny a Flight Level change request because the separation minima would not be met once vertical separation was lost.

Flight Level changes can significantly improve flight efficiency by reducing fuel use. This is because there is no single Flight Level that provides an optimum cruising Flight Level over the substantial period of time that aircraft spend in procedural airspace. As the optimum, no-wind Flight Level increases throughout the flight (as fuel is burned and aircraft weight is reduced); the aircraft would need to climb to maintain optimum cruise efficiency. Additionally, higher or lower Flight Levels may be more efficient because of more favorable winds.

In addition to efficiency improvements, Flight Level changes can increase safety when turbulent conditions exist at the current Flight Level. A Flight Level change for this reason would reduce the risk of injury to passengers or cabin crew, and increase passenger comfort.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support the extended situational awareness applications such as ITP.

2.2.1.1.4 Aircraft Needs for Future Collision Avoidance [ADS-B Integrated Collision Avoidance]

A future collision avoidance system based on ADS-B could contain enhancements beyond the present TCAS capability; for example:

- A surveillance element that processes ADS-B data,
- A collision avoidance logic that makes use of the improved surveillance information in detecting and resolving collision threats,
- A cockpit display of traffic information (CDTI) that may include predictive traffic position, enhanced collision alerts, and related information,
- A means of presenting Resolution Advisory (RA) maneuver guidance to the flight crew, possibly in the horizontal dimension as well as vertical.

TCAS II systems requirements have been updated to incorporate a hybrid surveillance scheme (combining active TCAS interrogation and passive reception of ADS-B broadcast data) to further reduce interference with ground ATS in the Hybrid Surveillance application, RTCA DO-300 [45]. Future enhancements may use ADS-B data in horizontal miss-distance filtering to further reduce the number of unnecessary RAs. Other modifications may include the use of ADS-B information in aircraft trajectory modeling and prediction or for lateral RA guidance.

These early applications of ADS-B in enhanced TCAS systems, beyond improving the performance of those systems, will also serve to validate the use of ADS-B through years of flight experience. The use of ADS-B to either supplement TCAS/ACAS or drive an independent CAS needs to be studied and simulated, addressing such issues as:

- Interoperability with existing collision avoidance systems,
- Mechanisms for aircraft-aircraft maneuver coordination,
- Optimization of threat detection thresholds,
- Surveillance reliability, availability and integrity,
- Need for intruder aircraft capability and status information,
- Handling special collision avoidance circumstances such as RA sense reversals,
- Data correlation and display merge issues, etc.

Further studies and test validation will need to be conducted to ensure compatibility of ADS-B with existing systems. Investigations will also be conducted to assess the need for a separate crosslink channel to handle information requests (such as for tracked altitude and rate, maneuver coordination, intruder capability, etc.).

Ultimately, assuming full ADS-B equipage and successful validation, collision avoidance based on active interrogation of transponders could be phased out in favor of ADS-B. The broadcast positions and velocities from the surrounding aircraft and the predicted intersection of their paths with own aircraft will be used to identify potential conflicts. Horizontal trajectory prediction based on the ADS-B data could reduce the number of unnecessary alerts, and will result in more accurate conflict prediction and resolution.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support collision avoidance.

Because a threat of collision could arise from a failure in ADS-B, future collision avoidance applications may need a method to validate, independently, any ADS-B data they use. It might become possible to eliminate the need for independent validation if it is demonstrated that ADS-B can provide sufficient reliability, availability, and integrity to reduce, to an acceptable level, the risk that collision avoidance based on ADS-B would fail when the risk of collision arises from a failure of ADS-B.

Environment

The transitional environment will consist of mixed aircraft populations in any combination of the following equipage types:

- Users of ADS-B that are transponder equipped.
- Enhanced TCAS, that can broadcast and process ADS-B Messages to improve TCAS/ACAS surveillance systems.
- Legacy TCAS II, including Mode S transponders.

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- Sources and users of ADS-B that are not equipped with transponders.
- Aircraft equipped with transponders, but not with ADS-B.

<u>Operational Scenario</u>

The scenario used for analysis of the collision avoidance capability of ADS-B consists of two co-altitude aircraft initially in a parallel configuration with approximately 1.5 NM horizontal separation and velocities of 150 knots each. One of the aircraft performs a 180 degree turn at a turn rate of 3 degrees per second which results in a head on collision if no evasive action is taken. The false alarm scenario used for analysis consists of two aircraft in a head-on configuration both with speeds of 150 knots.

2.2.1.1.5 Aircraft Needs While Performing Spacing Applications [FIM-S]

A combination of FMS and ADS-B IN / CDTI technology will enable pilots to assist in maintenance of aircraft spacing appropriate for a segment of an arrival and approach. At busy airports today aircraft are often sequenced at altitude to intervals of 10 to 12 miles. If looked at in terms of time over a point, the aircraft are roughly 80 seconds apart. Other than the cleared arrival flight path, pilots do not know the overall strategy or which aircraft are involved. Controllers begin speed adjustments and off arrival vectoring to assist in maintaining this interval and in achieving mergers of traffic. As the aircraft arrive at the runway, the spacing has in some cases been reduced to 2.5 miles or 55 seconds at approach speed. The speed adjustments and vectoring are an inefficiency that is accepted in the name of safety.

With ADS-B IN spacing applications, the pilot can assist the controller's efforts to keep the spacing appropriate for the phase of flight. This is not to say that the pilot assumes separation responsibility, but rather assists the controller in managing spacing, while flying a prescribed arrival procedure. The arrival procedures could be built so that with the normally prevalent winds, aircraft could be fed into the arrival slot with a time interval that would hold fairly constant through a series of speed adjustments. The speeds, allowable speed tolerance and desired spacing would all be defined by the procedure or specified by the controller based on ground automation systems.

Procedures need to be developed to accommodate merges; this could be done on the aircraft by the use of Required Time of Arrival, or on the ground using the ATC automation ground systems. The benefits would not only be in fuel savings but in reduced ATS communications requirements and increased capacity as standard operating procedures would govern more of the arrival operations.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support a terminal spacing application.

<u>Environment</u>

Spacing may occur in all operational domains. The subsequent scenario will focus on a terminal spacing application.

Operational Scenario

Terminal spacing will start at approach control and end at landing. Two aircraft are in a high volume terminal environment with mixed equipage. Both aircraft are under positive control by the terminal area controller, who issues an instruction to the in-trail aircraft to maintain a fixed separation (distance or time) behind the lead aircraft. The in-trail aircraft has an ADS-B IN CDTI to display all of the aircraft involved in the maneuver.

ADS-B IN spacing applications in the terminal domain can assist flight crews in the final approach. An opportunity for spacing occurs with aircraft cleared to fly an FMS 4D profile to the final approach fix. Another aircraft can perform ADS-B IN spacing to follow the lead aircraft using a CDTI that provides needed cues and situational data on the lead and other proximate aircraft. In this scenario, spacing allows a lesser equipped aircraft to fly the same approach as the FMS-equipped aircraft. The in-trail aircraft will maintain minimum separation standards, including wake vortex limits, with respect to the lead aircraft.

Specific scenarios include, but are not limited to:

1. Common route on arrival (where an aircraft is merged between two other aircraft in an arrival stream)

2. IM turn prior to merge (where path stretching or shortening is used to adjust spacing when speed changes alone would not be sufficient),

3. Arrivals supporting Optimized Profile Descents (OPD)

4. Crossing runways

5. Departure spacing

6. Dependent runway spacing

2.2.1.1.6 Aircraft Needs for Delegated Separation Assurance and Sequencing [FIM-DS, FIM-DSWRM]

Delegated separation applications are an operational concept in which the participating aircraft have the freedom to select their path and speed in real time. Research is in progress to fully develop operational concepts and requirements for delegated-separation. Delegated separation applications use the concept of “alert” and “protected” airspace surrounding each aircraft. In this concept, both general aviation and air carriers would benefit. Aircraft operations can thus proceed with due regard to other aircraft, while the air traffic management system would monitor the flight’s progress to ensure safe separation.

Delegated separation applications include a transfer of responsibility for separation assurance from ground based ATC to aircraft pairs involved in close proximity encounters. The delegation of responsibility may not be for all dimensions i.e., ATC may only delegate a responsibility for cross track separation from a particular aircraft to the flight crew. In this scenario ATC would retain the responsibility for longitudinal (along-track) separation and altitude separation from all other aircraft. Per Table 2-1, participating aircraft will be specially equipped with high accuracy and high integrity navigation capabilities and high reliability ADS-B capability for these increased criticality flight operations. The airborne separation assurance function includes separation monitoring, conflict prediction, and providing guidance for resolution of predicted conflicts.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support aircraft needs while performing delegated separation applications.

Note that to support delegated-separation, aircraft must be able to acquire both state vector and intent information for an approaching aircraft at the required operational range.

Environment

Each delegated separation applications aircraft supports electronically enhanced visual separation using a cockpit display of traffic information. All delegated separation applications aircraft perform conflict management and separation assurance. The pilot has available aircraft position, velocity vector information, and may have tactical intent information concerning proximate aircraft. Instead of negotiating maneuvers, the pilot uses "rules of the air" standards for maneuvers to resolve potential conflicts, or automatic functions that provide proposed resolutions to potential conflicts. There is a minimal level of interaction between potentially conflicting aircraft. Each aircraft in delegated separation applications airspace broadcasts the ADS-B state vector; higher capability aircraft equipped with flight management systems may also provide intent information such as current flight path intended and next path intended.

Only relevant aircraft will be displayed on the CDTI although hundreds of aircraft may be within the selected CDTI range, but well outside altitudes of interest for conflict management. Once both aircraft have been cleared for delegated-separation, the ATS provider will monitor the encounter but is not required to intervene.

Operational Scenario

Delegated separation applications are applicable in all operational domains, including, for example, en route aircraft overflying high density terminal airspace containing both airborne and airport surface traffic. The worst case conflict is two high speed commercial aircraft converging from opposite directions. Each aircraft has a maximum speed of 600 knots, resulting in a closure speed of 1200 knots (note that at coastal boundaries and in oceanic airspace, the potential exist for supersonic closure speeds of 2000 knots). A minimum advance conflict notice of two minutes is required to allow sufficient time to resolve the conflict

Messages to indicate intended trajectory are used to reduce alerts and improve resolution advisories. These intent messages include information such as: a) target altitude for aircraft involved in vertical transitions; and b) planned changes in the horizontal path.

The specific scenario used for evaluation of the delegated separation applications requirements consists of two aircraft traveling with a speed of 300 knots each. The aircraft are initially at right angles to each other. One of the aircraft executes a 90 degree turn with a 30 degree bank angle. The geometry is such that a collision would occur if no evasive action were taken. A conflict alert should be issued with a 2 minute warning time.

The false alarm delegated separation applications scenario assumes a separation standard of 2 NM. Two aircraft approach each other in a head-on configuration. Each aircraft travels at a speed of 550 knots. The final horizontal miss distance of the two aircraft is 13500 feet, slightly greater than the assumed separation standard. It is desired to keep false alarm rates low.

2.2.1.1.7 Aircraft Needs for Delegated Separation in Oceanic / Low Density En Route Airspace [ICSR, DS-C, DS-P]

This scenario addresses ADS-B requirements for aircraft performing delegated-separation while operating in oceanic or low density en route airspace. In such an operational environment there is a need to support cockpit display of traffic information at relatively longer ranges than for operations in higher density airspace.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support aircraft needs while performing delegated separation in low density en route airspace.

<u>Environment</u>

Participating aircraft are in oceanic or low density en route airspace performing delegated separation. Each participating aircraft supports an extended range cockpit display of traffic information. The pilots have available state vector, identification, and intent information concerning proximate aircraft. (Some near-term operational environments may allow delegated-separation without provision of full intent information, but require at least a 90 mile range in the forward direction).

<u>Operational Scenarios</u>

For these scenarios, all aircraft within the 90 mile range are ADS-B equipped and have CDTI. The pilot can elect to display all aircraft or relevant aircraft. Once participating aircraft are cleared for delegated-separation, the ATS provider will monitor the encounter but is not required to intervene. Scenarios include in-trail climb and descent, spacing, passing, and separation assurance.

2.2.1.1.8 Aircraft Needs While Performing Delegated Separation Simultaneous Approaches [PCSPA, ICSPA]

Operational improvements through the use of ADS-B for closely spaced runway operations are categorized as delegated separation applications. ADS-B supported applications will enable increased capacity at airports currently without PRM support. ADS-B permits faster detection times for the blunder, resulting in the ability to operate with lower separations between runways for simultaneous approaches. By providing information in the cockpit, the pilot can detect and react to a blunder without incurring delays associated with the controller-to-pilot communication link. Currently, allowances are made for such communication problems as blocked transmissions and non-receipt of controller maneuver instructions. These allowances are needed to achieve desired levels of safety but they result in greater separation between runways than would be required if pilots received the critical information more quickly. Note that the example ICSPA application described in Appendix J of RTCA DO-289 [44] has ATC delegating responsibility for cross track separation to the airborne segment while retaining separation responsibility for along track and altitude separation. The high level requirements for this example ICSPA application are provided in Table 2-3.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support aircraft needs while performing simultaneous independent approaches.

Environment

The environment includes aircraft on final approach to parallel runways as well as aircraft in the runway threshold area. ADS-B will be used to assure safe separation of adjacent aircraft.

Operational Scenarios

The scenario used for evaluation of closely spaced parallel runway approaches was a 30 degree blunder.

- Case 1: Runway centerline separation is 1000 feet.
- Case 2: Runway centerline separation is 2500 feet.
- Evader aircraft speed is 140 knots; intruder aircraft speed is 170 knots.
- The intruder aircraft turns 30 degrees, at 3 degrees per second, with a resulting near mid-air collision.
- A false alarm scenario consists of the two runway spacings with normal approaches and landings.
- Plant noise (normal aircraft dynamics in flight) is added to the aircraft trajectories to simulate total system error in the approach.

2.2.1.1.9 Aircraft Needs for Airport Surface Situational Awareness and Surface Alerting [SURF, SURF IA]

On the airport surface, ADS-B may be used in conjunction with a CDTI to improve safety and efficiency. The pilot could use CDTI and a moving map display for basic surface situational awareness. Advanced surface applications could support traffic alerting, low visibility taxi guidance and surface spacing. ADS-B used in conjunction with a moving map display may be used to show cleared taxi travel paths. Other proximate vehicles within the surface movement area and aircraft may also be identified using ADS-B information. At night, or at times of poor visibility, the airport surface digital map may be used for separation and navigation purposes. To support spacing on the airport surface, the in-trail aircraft needs to monitor the position and speed of the lead aircraft and to detect changes of speed to ensure that safe separation is maintained.

An additional operational need is for detection and alerting of unauthorized aircraft intrusion into the runway and taxiway protected area. Runway incursion detection and alerting while operating on the airport surface is different from airborne conflict detection. Because of the geometry and dynamics involved, extended projection of aircraft position based on current state vector is not feasible for runway incursion detection; however, projections on the order of 5 seconds may be feasible.

See Table 2-2 for the information exchange needs and Table 2-4 for operational performance requirements to support aircraft needs while operating on the airport surface.

Environment

The environment includes aircraft and vehicles moving on the airport surface (i.e., runways and taxiways), as well as approaching and departing aircraft. ADS-B will be used to monitor this operational environment.

Operational Scenarios

Blind Taxi:

The aircraft are taxiing in conditions of impaired visibility (down to 100 meters RVR). One aircraft is following another, with both maintaining 30 knots. The desired spacing between the aircraft while moving is 150 meters (nose to tail). The lead aircraft decelerates at 1.0 m/sec^2 until it stops. The pilot in the following aircraft is alerted to the lead aircraft's deceleration. Pilot reaction time is 0.75 seconds. The in-trail aircraft deceleration is 1.0 m/sec^2 to a stop. The required minimum separation is 50 meters under such conditions (nose to tail).

Runway Incursion:

An aircraft is on final approach while another aircraft is stopped at the hold short line, approximately 50 m from the runway edge. The stopped aircraft begins to accelerate at 1.0 m/ sec^2 and intrudes onto the runway. An alert should be generated approximately 5 seconds before the aircraft intrudes onto the runway.

2.2.1.1.10 Aircraft Needs for Self Separation – [Flow Corridors and Self Separation Applications]

The long term roadmap for ADS-B In surveillance applications is the concept of self separation where the flight crew assumes the primary responsibility for separation assurance for a defined segment of the flight and ATC assumes a secondary monitoring function. As part of their responsibility, the flight crew is granted authority to modify their trajectory within defined degrees of freedom without renegotiating with ATC. The self-separation portion of the flight generally terminates with an agreed time of arrival at the point where separation responsibility is transferred back to the ATC. The application can be implemented in either a homogeneous environment, in which all aircraft are self-separating, or in a mixed-operations environment, in which some aircraft are receiving a separation service from the ATC. In mixed operations, ATC is not responsible for separating any aircraft where any of the relevant aircraft includes a self-separating aircraft.

Per Table 2-1, this concept could require increased performance requirements that would support this category of higher integrity airborne functions. It could also potentially require the broadcast of new classes of data such as intent data and/or wake vortex parameters that are not currently required for existing categories of ADS-B In applications.

2.2.1.2 ANSP Separation Services

The following discussion focuses on ground ATS surveillance and automation systems that use ADS-B surveillance information pertaining to aircraft within the area of operational control (ADS-B Out). A summary of the current ATS surveillance system capabilities is provided in Table 2-5. While the individual parameter values in the table may not be directly applicable to the ADS-B system, the ADS-B System is expected to support equivalent or better overall system level performance for the cited applications. ADS-B Out requirements, developed for the regional mandates, are expected to satisfy the required surveillance performance for the ADS-B In air-to-air applications.

For aircraft required to support ATS surveillance in en route and terminal airspace, a capability to independently validate the ADS-B surveillance information is likely to be required [6]. Alternative validation means are under study. An example of this independent validation would be in areas of radar coverage the use of radar ranging and azimuth data to validate the received ADS-B position messages.

The current en route and terminal surveillance environments consist of primary radars and SSRs providing high altitude and terminal airspace coverage. While air carrier operations generally stay within en route and terminal radar coverage, commuter, corporate, and general aviation operators frequently conduct operations that extend outside radar coverage. Existing radar technology provides surveillance performance and capabilities that fully support the current ATS operational concepts, but the benefits in some low traffic areas do not justify the cost of a full radar system. Improved surveillance capabilities, based on ADS-B, will provide in a cost effective manner, the extended coverage necessary to support advanced ATS capabilities. ADS-B broadcasts will be received, processed, fused with other traffic management information, and provided to the system having ATS jurisdiction for that airspace.

Table 2-5: Summary of Expected ATS Provider Surveillance and Conflict Management Current Capabilities for Sample Scenarios

	Operational Capability			
Information ↓	**En Route**	**Terminal**	**Airport Surface**	**Parallel Runway Conform Mon.**
Initial Acquisition of A/V Call Sign and A/V Category	within 24 sec.	within 10 sec.	within 10 sec.	n/a
Altitude Resolution (ft) (Note 5)	25	25	25	25
Horizontal Position Error	388 m @ 200 NM 116 m @ 60 NM 35 m @ 18 NM	116 m @ 60 NM 35 m @ 18 NM	3 m. rms, 9 m. bias [15]	9 m.
Received Update Period (Note 2)	12 sec. [10]	5 sec. [15]	1 sec.	1 sec.
Update Success Rate	98%	98%	98% [15]	98%
Operational Domain Radius (NM)	200	60	5	The lesser of 30 NM, or the point where the aircraft intercepts the final approach course
Operational Traffic Densities (# A/V) (Note 3)	1250 [15]	750 [15]	100 in motion; 150 fixed	50 dual; 75 triple; w/o filter: 150
Service Availability (%) (Note 4)	99.999 99.9 (low alt)	99.999 99.9 (low alt)	99.999	99.9

Table 2-6: Additional Expected Capabilities Appropriate for ADS-B Supported Sample Scenarios

	Operational Capability			
Information ↓	**En Route**	**Terminal**	**Airport Surface**	**Parallel Runway Conform Mon.**
Altitude Rate Error (1σ)	1 fps	1 fps	1 fps	1 fps
Horizontal Velocity Error (1σ)	5 m/s	0.6 m/s	0.3 m/s	0.3 m/s
Geometric Altitude	Yes	Yes	Yes	Yes

Notes for Table 2-5 and Table 2-6:

n/a (not applicable) = the requirement is not stressful and would not be higher than any other requirement, i.e., does not drive the design.

1) *References are provided where applicable. Else, best judgment was used to obtain performance data.*
2) *Received update period is the period between received state vector updates. A/V Call Sign and A/V Category can be received at a lower rate.*
3) *One or multiple ground receivers may be used in the operational domain to ensure acceptable performance for the intended traffic load. The numbers in the table indicate the number of aircraft expected to participate in or affect a given operation.*

(Refer to Table 2-4 for requirements which are based on operational traffic densities derived from the Los Angeles basin model).

4) *Service availability includes any other systems providing additional sources of surveillance information.*
5) *Altitude accuracy: Some aircraft currently have only 100 foot resolution capability.*
6) *Table 2-5 and Table 2-6 were taken from RTCA DO-242A, Table 2-9(a) and Table 2-9(b), respectively.*

As ADS-B is introduced, it is important for ATS to retain the flexibility to continue to use the existing surveillance systems based on SSR transponders. Therefore, it can be expected that in radar controlled environments, equipping with ADS-B will not initially eliminate the current requirement to carry SSR transponders. It may be possible in some cases for an aircraft to equip with ADS-B without adding a transponder. Many automation systems rely on SSR Mode A codes to identify aircraft. Use of ADS-B Reports by the ground surveillance systems may require correlation with an ATS assigned SSR Mode A code for some applications.

Currently ground-based surveillance systems are mostly independent of aircraft navigation systems and surveillance data is largely verified through ground surveillance monitoring systems. Initially, some level of navigation independence and verification will continue to be required for ATS surveillance applications in certain airspace. The surveillance capabilities in Table 2-5 are acceptable because they are part of the current airspace management system, which has this level of independence. A detailed failure modes and effects analysis should be performed before a surveillance system that is less independent of aircraft navigation systems is approved for operational use.

Note: *Surveillance of air traffic plays a significant role in aviation security. For security reasons, ATS surveillance requirements in certain airspace may include a need for independent sources of surveillance information.*

2.2.1.2.1 En Route and Terminal Airspace

Current requirements in the En Route and Terminal airspace are deemed to be much less stressful than the other ADS- Out applications. This airspace may be further divided into the use of ADS-B Out in Non Radar Airspace (NRA) and ADS-B Out in Radar Airspace (RAD). Characteristics of surveillance systems currently in use in the NAS for En Route and Terminal are listed in Table 2-5. These characteristics are provided for information and comparison only. ADS-B will support equal or better surveillance application performance (e.g., see Table 2-6). Traffic densities and operational domain radius can be used for expected loading on the ADS-B data link broadcast medium.

The high level performance requirements for the existing ADS-B Out NRA, RAD and APT applications are contained in Table 2-7.

The existing degree of independence between navigation and surveillance will be needed in the future until combined system performance standards are developed.

1924 **Table 2-7: ADS-B Out Applications to Support ATC Surveillance - Minimum Performance Requirements**

Scenario →	NRA – 5 NM EnRoute	NRA – 3 NM EnRoute / Terminal	RAD – 5 NM Enroute	RAD – 3 NM Terminal	RAD–2.5 NM Approach	RAD-2.0 NM Approach	RAD Independent Parrallel Approach	APT
SPR Doc →	**DO-303 / ED-126**	**DO-303 / ED-126**	**DO-318 / ED-161**	**DO-318 / ED-161**	**DO-318 / ED-161**	**DO-318 / ED-161**	**DO-318 / ED-161**	**DO-321 / ED-163**
NAC_P	5	6	7	8	8	8	8	6 for V0 8 for V2
NAC_V	N / A	N / A	N / A	N / A	N / A	N / A	N / A	
Vertical Accuracy, 95%	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	38.1m / 125 ft	
SIL	2	2	3	3	3	3	3	2 for V1 3 for V2
NIC	4	5	5	6	7	7	7	0
SDA	2	2	2	2	2	2	2	≥ 1

1925 ***Note:*** *Refer to the FAA Final ADS-B OUT Rule.*

1926

2.2.1.2.2 Airport Surface

On the airport surface, ADS-B will provide improved surveillance within the surface movement area. The system will display both surface vehicles and aircraft within the surface movement area to provide a comprehensive view of the airport traffic. Surveillance information will be provided to all control authorities within the airport, coverage will be provided for moving and static aircraft and vehicles, and positive identification will be provided for all authorized movements.

ATS will utilize ADS-B information to provide services consistent with a move toward Delegated separation applications. In this environment, a majority of aircraft will need to be equipped with ADS-B in order to provide significant benefit to the user or ATS service providers.

In the early stages of implementation, functions supported by ADS-B can be integrated with the controller's automation tools to provide several benefits including:

1) Reduction in taxi delays, based on improved controller situational awareness,

2) Operation in zero-visibility conditions for equipped aircraft and airport surface vehicles, and

3) Improved controller ability to predict and intervene in potential incursions, along with a reduction in false alarms.

In the long term, ADS-B would become the principal surveillance system to support surveillance of the airport surface movement area. For air traffic management, controllers, and air carriers, the greatest additional benefits would result in reducing taxi delays and coordinating with arriving and departing traffic. These long-term benefits are based on the use of cockpit automation and exchange of data between the cockpit and airport automation systems. This includes moving map displays, data linking of taxi routes, etc.

The airport traffic management system continuously monitors each aircraft's current and projected positions with respect to all possible conflicts. Detectable conflicts should include:

- Potential collision with a moving/active aircraft or vehicle,
- Potential collision with a known, static obstacle, aircraft, or vehicle,
- Potential incursion into a restricted area (weight/wingspan limited areas, closed areas, construction areas, etc.).
- Potential incursion into a controlled area (runways, taxiways, ILS critical areas, etc.).

It may be necessary for the ATS system to make use of known routes and conformance monitoring to effectively detect these conflicts.

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Aircraft type classification, status and clearance information will play an important role in conflict management processing. Individual areas may be restricted to certain vehicles or aircraft and not others. For example, a taxiway may be off limits to vehicles over a specified weight. In this case, a conflict or taxiway incursion alert will be generated if a heavy vehicle approaches or enters the taxiway while a lighter vehicle would have unrestricted access. In addition, an aircraft may be cleared to enter selected areas at specific times. For example, if an aircraft is cleared for a runway, it may enter it without restriction. If an uncleared aircraft enters the runway, a runway incursion alert will be generated.

<u>Environment</u>

Operational environment includes airport movement area up to 1500 feet above airport level so as to cover missed approaches and low level helicopter operations. The surface movement area is that part of an airport used for the takeoff, landing, and taxiing of aircraft.

<u>Operational Scenario</u>

Participants are high-end aircraft performing taxi and departures during low visibility arrival operations (visibility less than 200 meters).

Aircraft are approaching an active runway with aircraft on final approach. ADS-B is used to provide the pilot and controller with alert information of potential conflicts. This alert information consists of an indication to the pilot and controller of the time remaining until a conflict will occur.

<u>Requirements</u>

See Table 2-2 for information exchange needs and see Table 2-5 and Table 2-6 for operational performance needs to support ATS surveillance on the airport surface.

Surface surveillance should interface seamlessly with terminal airspace to provide information on aircraft 5 NM from the touchdown point for each runway.

2.2.2 ATS Conformance Monitoring Needs

With ADS-B, ATS would monitor the ADS-B Messages ensuring that an aircraft maintains conformance to its intended trajectory. Conformance monitoring occurs for all controlled aircraft or airspace, and applies to all operational airspace domains. In the case of protected airspace or SUA, conformance monitoring is performed to ensure that an aircraft does not enter or leave a specific airspace.

In the terminal environment, the ATS provider will monitor the aircraft's reported position and velocity vector to ensure that the aircraft's current and projected trajectory is within acceptable bounds. The increased accuracy and additional information directly provided by the aircraft (via ADS-B), in comparison to radar-based monitoring, will result in quicker blunder detection and reduce false alarms.

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2.2.2.1 Operational Scenario (Parallel Runway Monitoring)

A specific example of conformance monitoring is PRM and simultaneous approach, a surveillance and automation capability that enables a reduction in minimum runway spacing for independent approaches to parallel runways in IMC. All aircraft participating in a given parallel approach should be ADS-B equipped.

Initial use of ADS-B for PRM could be achieved before full equipage by limiting access to parallel approaches at specified airports only to ADS-B equipped aircraft. This may not be practical until a significant number of aircraft are equipped with ADS-B. When sufficient aircraft are equipped for ADS-B, an evolution to the full use of ADS-B to support PRM can occur. At that time, radar-based PRM system would no longer be needed.

2.2.2.2 Requirements

See Table 2-2 for information exchange needs and see Table 2-5 and Table 2-6 for operational performance needs to support ATS parallel runway conformance monitoring.

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3 ADS-B and Airborne Systems Definition and Performance Requirements

This section defines, within the context of ASA operational applications, the ADS-B System and its functional and performance requirements. The system description and user equipage classifications are summarized in Section 3.1. The broadcast information element requirements are given in Section 3.2. System application requirements are given in Section 3.3. Subsystem requirements are stated in Section 3.4, and ADS-B output report characteristics supporting application needs are described in Section 3.5.

3.1 System Descriptions

3.1.1 ADS-B Subsystem Description (Transmit and Receive)

This section describes the ADS-B system, provides examples of ADS-B system architectures, and defines ADS-B equipage classes.

3.1.1.1 Context Level Description

Context diagrams, which are data flow diagrams at successive levels of system detail, are used to define information exchanges across system elements and indicate how required functions are partitioned. The following subsections present context diagrams for ADS-B at three successive levels of detail: (1) the ADS-B system level, (2) subsystem level, and (3) functional level.

3.1.1.1.1 System Level

ADS-B system level information exchange capabilities are illustrated in the top-level context diagram of Figure 3-1. As depicted in this and subsequent figures, four symbols are used to define data flows in context diagrams:

1. Entities external to the ADS-B Subsystem are identified by rectangles.
2. Data flows are labeled lines with directional arrowheads.
3. Processes are defined by circles.
4. Data storage or delays are indicated by parallel lines.

Information flows into or out of any context layer must be consistent with those identified at the next layer.

The ADS-B system level includes ADS-B subsystems supporting each participant and the means necessary for them to exchange messages over the broadcast medium. The ADS-B system accepts Ownship source data from each of N aircraft/vehicle interactive participants, B aircraft/vehicle broadcast-only participants, and G fixed ground broadcast-only participants, and makes it available through the RF medium to each of the other N interactive participants as well as R receive-only ground sites. Interactive ground facilities may also exist in some ADS-B systems.

In Figure 3-1, Ownship source data for each broadcasting participant are denoted by the subscript “o” and include:

Ownship geometric and air mass referenced state vector reports (SV_o) which include aircraft position, velocity, navigation integrity category (NIC_o) indicating integrity containment radius R_C of position data, and address, Ad_o.

Mode-status reports (MS_o) which include address, Ad_o, aircraft/vehicle identification ID_o (flight or tail number if enabled by user, and aircraft category), emergency/priority status, information on supported applications, and navigation accuracy categories indicating the accuracy of position (NAC_P) and velocity (NAC_V) data.

On-condition reports (OC_o) include aircraft/vehicle address Ad_o. Data for on-condition reports are accompanied as needed by appropriate control inputs (e.g., “transmit an ADS-B Message under these conditions” as opposed to following a strictly periodic pattern of transmission).

Messages transmitted by other ADS-B system participants are received by the onboard ADS-B subsystem and used to generate ADS-B Reports (indicated by subscript “i”) which are made available for onboard applications. The address, common to all message types, is used for correlating received information. System level requirements are given in §3.3 and format characteristics associated with the required information exchanges are summarized in §3.5.

3.1.1.1.2 Subsystem Level

Further details of the many-to-many information exchange supported by the ADS-B system are given in the subsystem level context diagram of Figure 3-2. Subsystems supporting each type of participant are shown in the figure with their respective user interfaces and associated message exchanges over the RF medium. As described above, the aggregate of all ADS-B subsystems interconnected over the broadcast medium comprises the ADS-B system.

Interactive Aircraft/vehicle participant system interfaces to the supporting ADS-B subsystem are illustrated in the upper left part of the figure. State vector source data (SV_o) are provided by the platform dynamic navigation systems and sensors. Mode-status and on-condition source data (MS_o, OC_o) are available from onboard flight status source data or by flight crew entry. This Ownship information is transmitted over the RF medium as appropriately encoded ADS-B Messages (M_o). Similarly defined messages are received from other participants (Mi), processed by the subsystem, and made available as ADS-B Reports (SV_i, MS_i, OC_i) to surveillance-related on-board applications. The operational mode is determined by the subsystem control logic, e.g., a different broadcast mode may be used while on the airport surface.

Functional capabilities and information flows for other classes of subsystems are also indicated in Figure 3-1. Other subsystem classes are aircraft/vehicle broadcast-only (requiring inputs from an onboard navigation system and database, but providing no output information to on-board applications); fixed ground broadcast-only (requiring previously surveyed data inputs); and ground receive-only (providing ADS-B Reports to support ATS and other applications). Subsystem control inputs are shown as dashed lines for each subsystem. Subsystem requirements are given in §3.4.

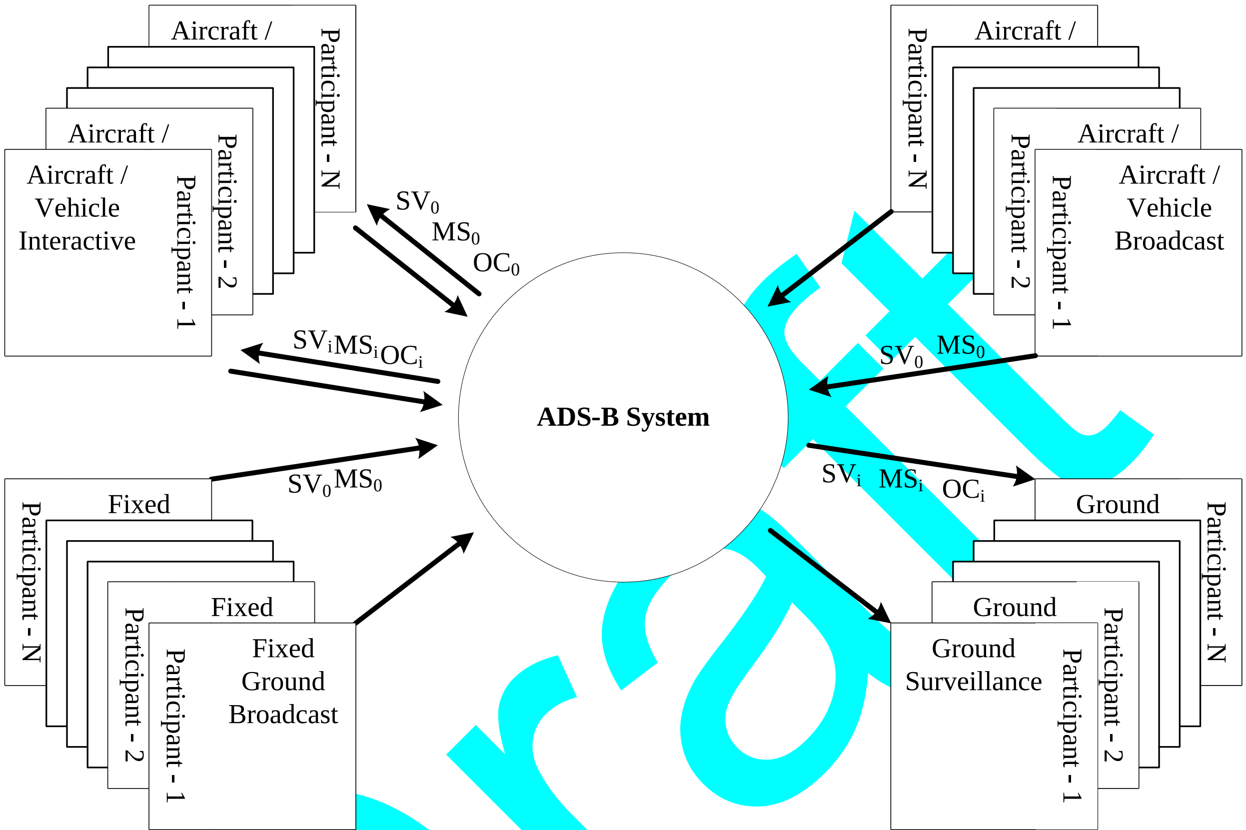
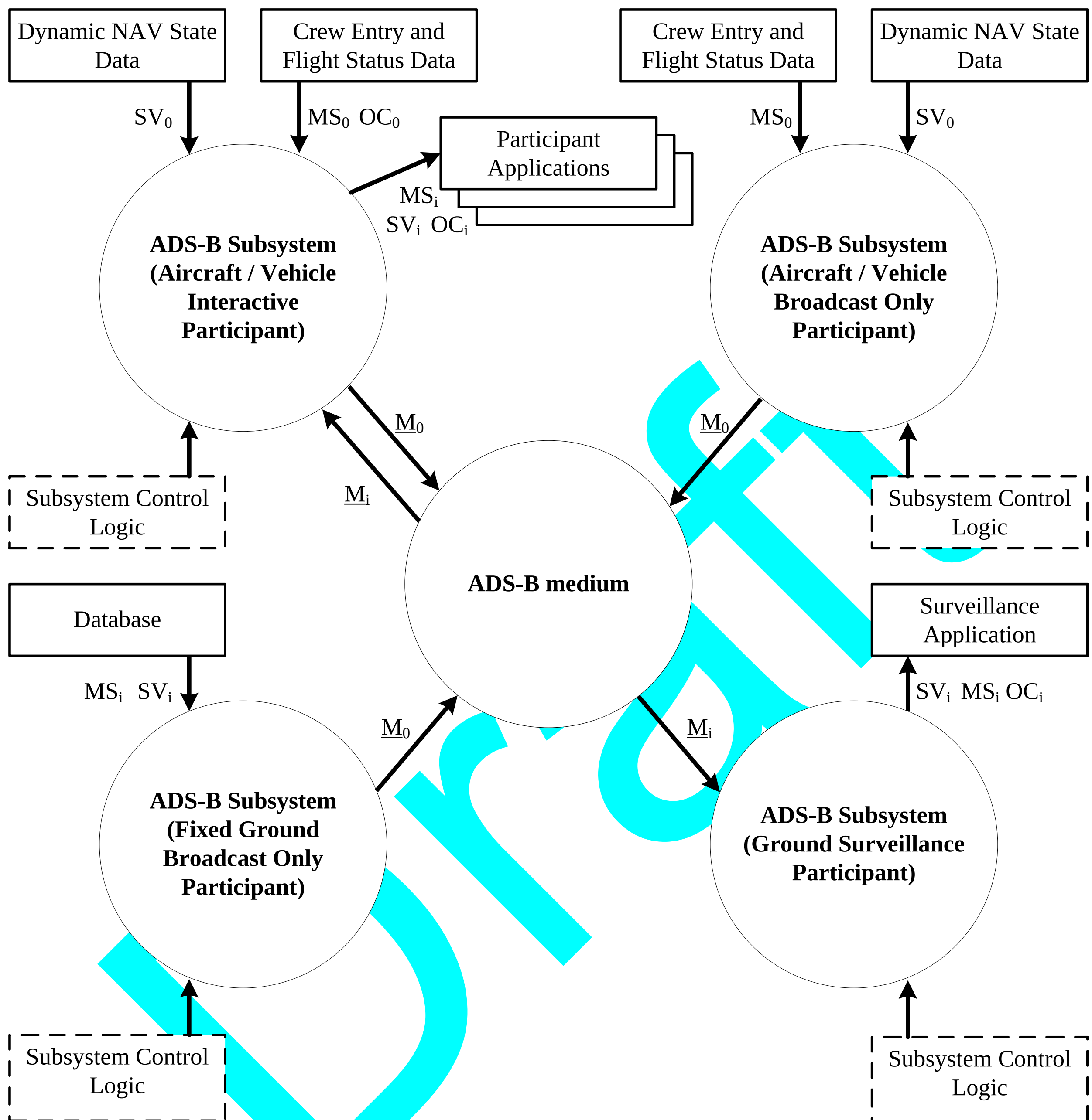


Figure 3-1: Illustrative ADS-B System Level Context Diagram

Abbreviations:

SV_o = own state vector source data
MS_o = own mode-status source data
OC_o = own event driven or on condition source data
SV_i = other participants' state vector reports
MS_i = other participants' mode-status reports
OC_i = other participants' on condition reports



<u>Figure 3-2:</u> ADS-B Subsystem Level Context Diagram for ADS-B System

<u>Note:</u> *M_0 represents own ship transmitted message, Mi denotes messages received from other participants. The vector notation, M denotes one or more messages, depending on implementation. Different participants may supply and / or use different types of information*

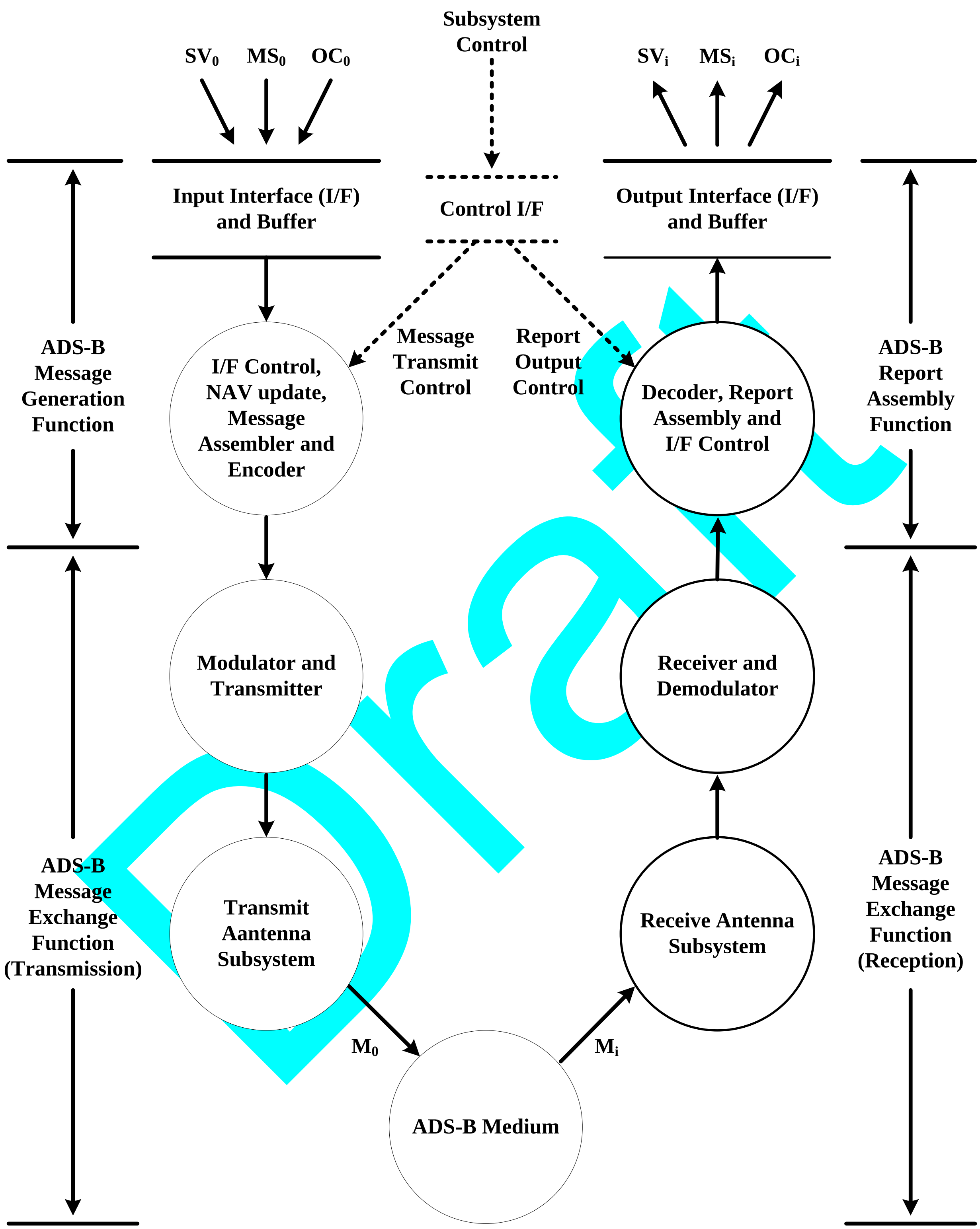


Figure 3-3: ADS-B Functional Level Context Diagram for Aircraft Interactive Subsystem

3.1.1.1.3 Functional Level

Subsystem functional partitioning and interfaces are illustrated for an interactive aircraft participant in the functional level context diagram of Figure 3-3. Functional capabilities required to (1) accept source data inputs and control information to the subsystem from onboard systems, and generate the required ADS-B Messages; (2) exchange messages with other ADS-B participants; and (3) assemble ADS-B Reports containing required information from other participants for use by onboard applications, are outlined here. Subsystem functional partitioning and interfaces for broadcast-only and receive-only participants are described by an appropriate subset of this functionality.

3.1.1.2 Participant Architecture Examples

Examples of ADS-B subsystem architectures and their interactions are given in Figure 3-4, Figure 3-5 and Figure 3-6. Figure 3-4 illustrates the minimum capabilities on-board aircraft A to support aid to visual acquisition and ADS-B traffic situational awareness with alerting on-board aircraft B.

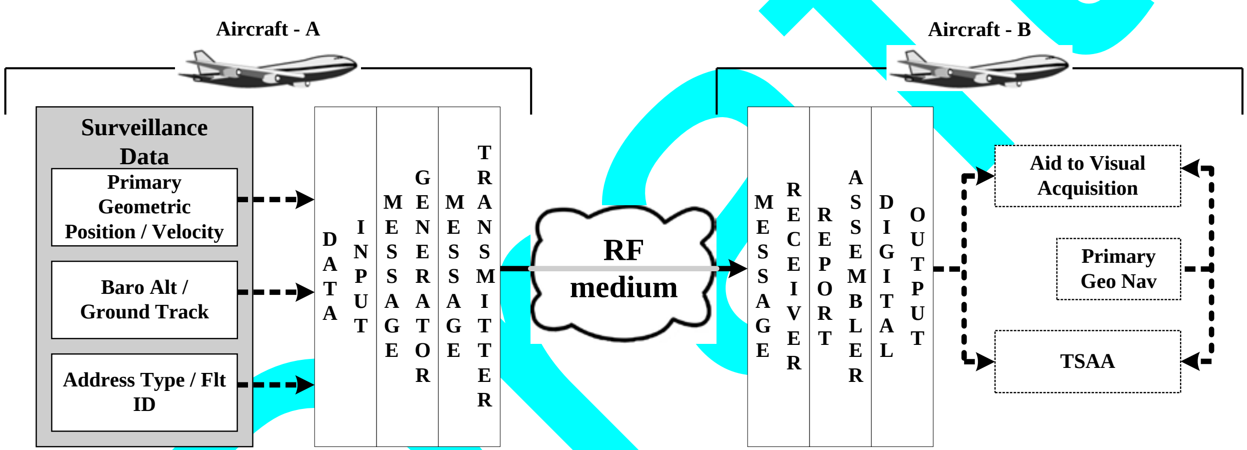


Figure 3-4: Example of A/C Pair Supporting Aid to Visual Acquisition and TSAA

Figure 3-5 illustrates expanded capabilities enabled by the more sophisticated onboard avionics. With more capable ADS-B transmit and receive avionics, and the ability to support appropriate user applications, each aircraft may be approved for more advanced ADS-B applications.

Figure 3-6 illustrates ADS-B applied to air-ground surveillance. The precise velocity, geometric and air mass data along with selected altitude and heading information provided by ADS-B enables advanced surveillance and conflict management implementations. Ground system track processing and correlation of ADS-B data with other ground derived surveillance data can provide an integrated view to ground automation and controller interfaces.

Approval for the above operational uses of ADS-B requires certification of ADS-B equipage integrated with other aircraft/vehicle and ground systems and demonstration of acceptable end-to-end performance. The approved system design must include the originating sources and the user applications necessary to support appropriate operational levels defined above. Interdependencies between the ADS-B subsystems,

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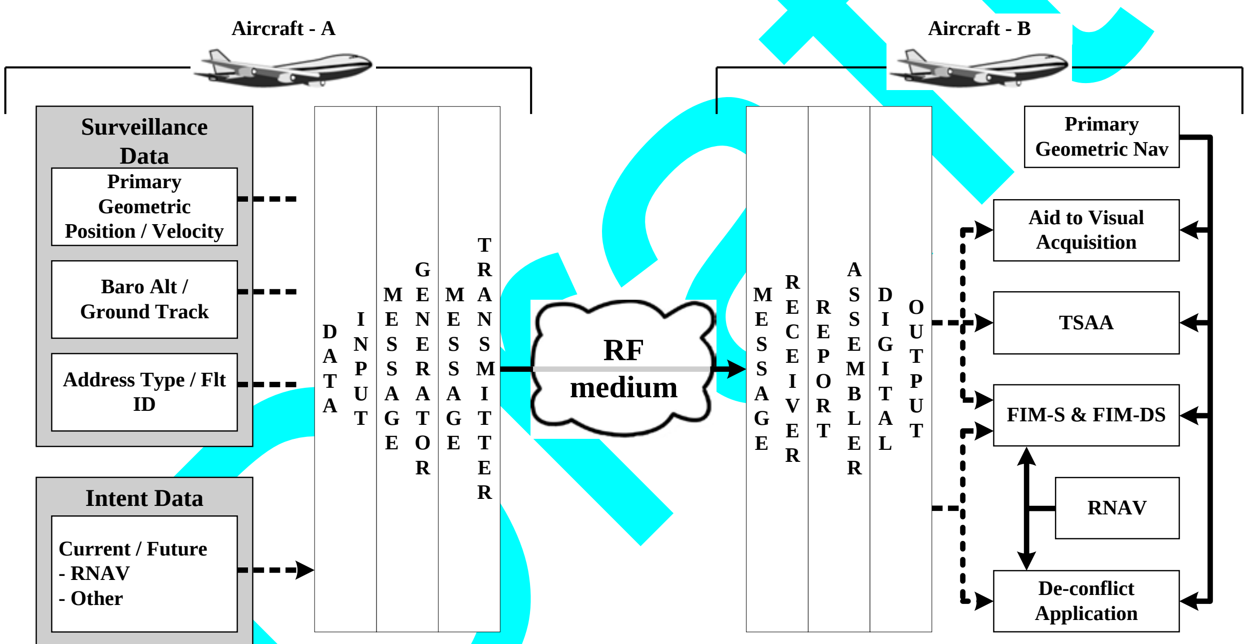
interfacing sources and user applications will probably need to be addressed as part of the subsystem certification process. The distributed elements of the total system comprising the operational capability typically will be individually certified.

3.1.1.3 Equipage Classifications

As illustrated above, ADS-B equipment must be integrated into platform architectures according to platform characteristics, capabilities desired and operational objectives for the overall implementation. The technical requirements for ADS-B have been derived from consolidation of the scenarios presented in Section 2 within the context of the use of the ADS-B System as primary-use capable. The operational capabilities are divided into hierarchical levels (with each level including all capabilities of the preceding level):

Aid to Visual Acquisition: basic state vector information

VSA and ITP: state vector information augmented with identification



<u>Figure 3-5:</u> Example of A/C Pair Capable of Supporting Advanced ADS-B Applications

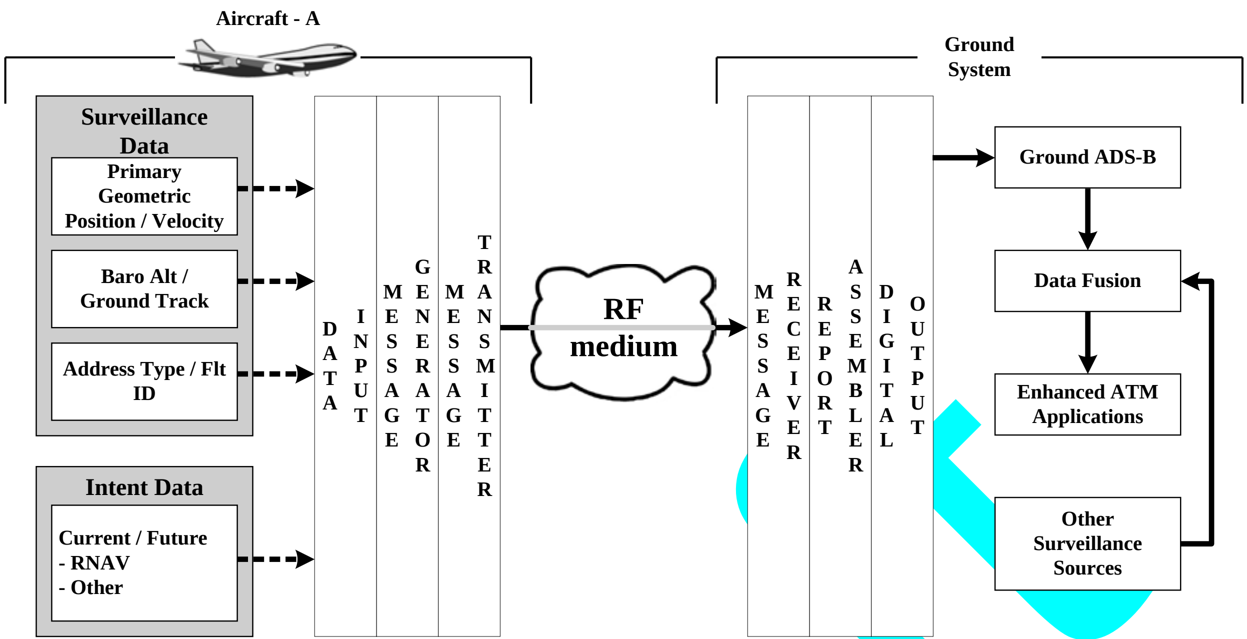


Figure 3-6: Example of ADS-B Support of Ground ATS Applications

ADS-B equipage is categorized according to the classes listed in Table 3-1. ADS-B equipage classes are defined in terms of the levels of operational capabilities discussed above. The classifications include airborne and ground participants, and include those that are fully interactive and those that only receive or transmit. In addition to defining equipage classifications the table summarizes salient features associated with these capabilities.

ADS-B systems used on surface vehicles are expected to require certification similar to that applicable to airborne ADS-B systems in order to ensure conformance to required transmission characteristics. If required due to spectrum considerations, surface vehicles must have an automatic means to disable transmission of ADS-B Messages when outside the surface movement area.

3.1.1.3.1 Interactive Aircraft/Vehicle ADS-B Subsystems (Class A)

Functional capabilities of interactive aircraft/vehicle subsystems are indicated in the context diagram of Figure 3-3. These subsystems accept own-platform source data, exchange appropriate ADS-B Messages with other interactive ADS-B System participants, and assemble ADS-B Reports supporting own-platform applications. Such interactive aircraft subsystems, termed Class A subsystems, are further defined by equipage classification according to the provided user capability.

The following types of Class A subsystems are defined in (Table 3-1):

Class A0: Supports minimum interactive capability for participants. Broadcast ADS-B Messages are based upon own-platform source data. ADS-B Messages received from other aircraft support generation of ADS-B Reports that are used by on-board applications (e.g., CDTI for aiding visual acquisition of other-aircraft tracks by the own-aircraft's air crew). This equipage class may also support interactive ground vehicle needs on the airport surface.

Class A1 supports all class A0 functionality and additionally supports, e.g., ADS-B-based airborne conflict management and other applications at ranges < 20 NM. Class A1 is intended for operation in IFR designated airspace.

Class A2: Supports all class A1 functionality and additionally provides additional range to 40 NM and information processing to support longer range applications, e.g., Delegated Separation, FIM-DS.

Class A3: Supports all class A2 functionality and has additional range capability out to 90 NM, to support extended range applications, e.g., Delegated Separation in Oceanic / Low Density EnRoute.

In addition, individual ADS-B data links may further refine Class A equipage classes to distinguish between single antenna and diversity antenna subsystems. It is left to the individual ADS-B data link MOPS to decide on equipage class antenna diversity requirements. To distinguish any Class A equipage class for which antenna diversity is required to be completely Class compliant, but single antenna is permitted, single antenna subsystems for that Class should be designated with an "S".

Note: *For example, ADS-B data links requiring antenna diversity to be considered Class A1 compliant but permitting single antenna installations would use the designation "A1S" for single antenna subsystems. The Single Antenna Flag field defined in §3.2.31 is used to indicate whether the ADS-B Transmitting Subsystem is operating with a single antenna or diversity.*

3.1.1.3.2 Broadcast-Only Subsystems (Class B)

Some ADS-B system participants may not need to be provided information from other participants but do need to broadcast their state vector and associated data. Class B ADS-B subsystems meet the needs of these participants. Class B subsystems are defined as follows (Table 3-1):

Class B0: Aircraft broadcast-only subsystem, as shown in Figure 3-2. Class B0 subsystems require an interface with own-platform navigation systems. Class B0 subsystems require transmit powers and information capabilities equivalent to those of class A0.

Class B1: Aircraft broadcast-only subsystem, as shown in Figure 3-2. Class B1 subsystems require an interface with own-platform navigation systems. Class B1 subsystems require transmit powers and information capabilities equivalent to those of class A1.

Class B2: Ground vehicle broadcast-only ADS-B subsystem. Class B2 subsystems require a high-accuracy source of navigation data and a nominal 5 NM effective broadcast range. Surface vehicles qualifying for ADS-B equipage are limited to those that operate within the surface movement area.

Class B3: Fixed obstacle broadcast-only ADS-B subsystem. Obstacle coordinates may be obtained from available survey data. Collocation of the transmitting antenna with the obstacle is not required as long as broadcast coverage requirements are met. Fixed obstacle qualifying for ADS-B are structures and obstructions identified by ATS authorities as a safety hazard.

In addition, individual ADS-B data links may further refine Class B equipage classes to distinguish between single antenna and diversity antenna subsystems. It is left to the individual ADS-B data link MOPS to decide on equipage class antenna diversity requirements. To distinguish any Class B equipage class for which antenna diversity is required to be completely Class compliant, but single antenna is permitted, single antenna subsystems for that Class should be designated with an "S".

Note: *For example, ADS-B data links requiring antenna diversity to be considered Class B1 compliant but permitting single antenna installations would use the designation "B1S" for single antenna transmitters. The Single Antenna Flag field defined in §3.2.31 is used to indicate whether the ADS-B Transmitting Subsystem is operating with a single antenna or diversity.*

Table 3-1: Subsystem Classes and Their Features

Class	Subsystem	Description	Features	Comments
Interactive Aircraft/Vehicle Participant Subsystems (Class A)				
A0 (1)	Minimum Interactive Aircraft/Vehicle	Supports basic enhanced visual acquisition	Lower transmit power and less sensitive receive than Class A1 permitted.	Minimum interactive capability with CDTI.
A1 (1)	Basic Interactive Aircraft	A0 plus provides standard range	Standard transmit and receive	Provides standard range
A2 (1)	Enhanced Interactive Aircraft	A1 plus improved range	Standard transmit power and more sensitive receive. Interface with avionics source required for TS.	Supports longer range applications
A3 (1)	Extended Interactive Aircraft	A2 plus long range	Higher transmit power and more sensitive receive. Interface with avionics source required for TS.	Extends range for advanced applications.
Broadcast-Only Participant Subsystems (Class B)				
B0	Aircraft Broadcast only	Supports A0 Applications for other participants	Transmit power may be matched to coverage needs.	Enables aircraft to be seen by Class A and Class C users.
B1	Aircraft Broadcast only	Supports A1 Applications for other participants	Transmit power may be matched to coverage needs.	Enables aircraft to be seen by Class A and Class C users.
B2	Ground vehicle Broadcast only	Supports airport surface situational awareness	Transmit power matched to surface coverage needs. High accuracy position input required.	Enables vehicle to be seen by Class A and Class C users.
B3	Fixed obstacle	Supports visual acquisition and airborne conflict management	Fixed coordinates. No position input required. Collocation with obstacle not required with appropriate broadcast coverage.	Enables NAV hazard to be detected by Class A users.
Ground Receive Subsystems (Class C)				
C1	ATS En route and Terminal Area Operations	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	Supports provision of ATS Surveillance for ADS-B System Participants where adequate Air-Ground range and integrity have been demonstrated. Expected en route coverage out to 200 NM. Expected terminal coverage out to 60 NM.
C2	ATS Parallel Runway and Surface Operation	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	Expected approach coverage out to 30 NM, or – if of lesser value - the point where the aircraft intercepts the final approach course. Expected surface coverage out to 5 NM.
C3	Flight Following Surveillance	Supports private user operations planning and flight following	Does not require ATS interface. Certification requirements determined by user application.	Coverage determined by application.

Note: *ADS-B data links can achieve required equipage class performance through the tradeoff between transmit power and receive sensitivity.*

3.1.1.3.3 Ground Receive-Only Subsystems (Class C)

Surveillance state vector reports, mode-status reports, and on-condition reports are available from ADS-B system participants within the coverage domain of ground ADS-B receive-only, or Class C subsystems. The following Class C subsystems are defined (Table 3-1):

Class C1: Ground ATS Receive-Only ADS-B Subsystems for En Route and Terminal area applications. Class C1 subsystems should meet continuity and availability requirements determined by the ATS provider.

Class C2: Ground ATS Receive-Only ADS-B Subsystems for approach monitoring and surface surveillance applications. Class C2 subsystems have more stringent accuracy and latency requirements than Class C1 systems. Class C2 systems may be required, depending upon the ADS-B System design, to recognize and process additional ADS-B Message formats not processed by Class C1 subsystems.

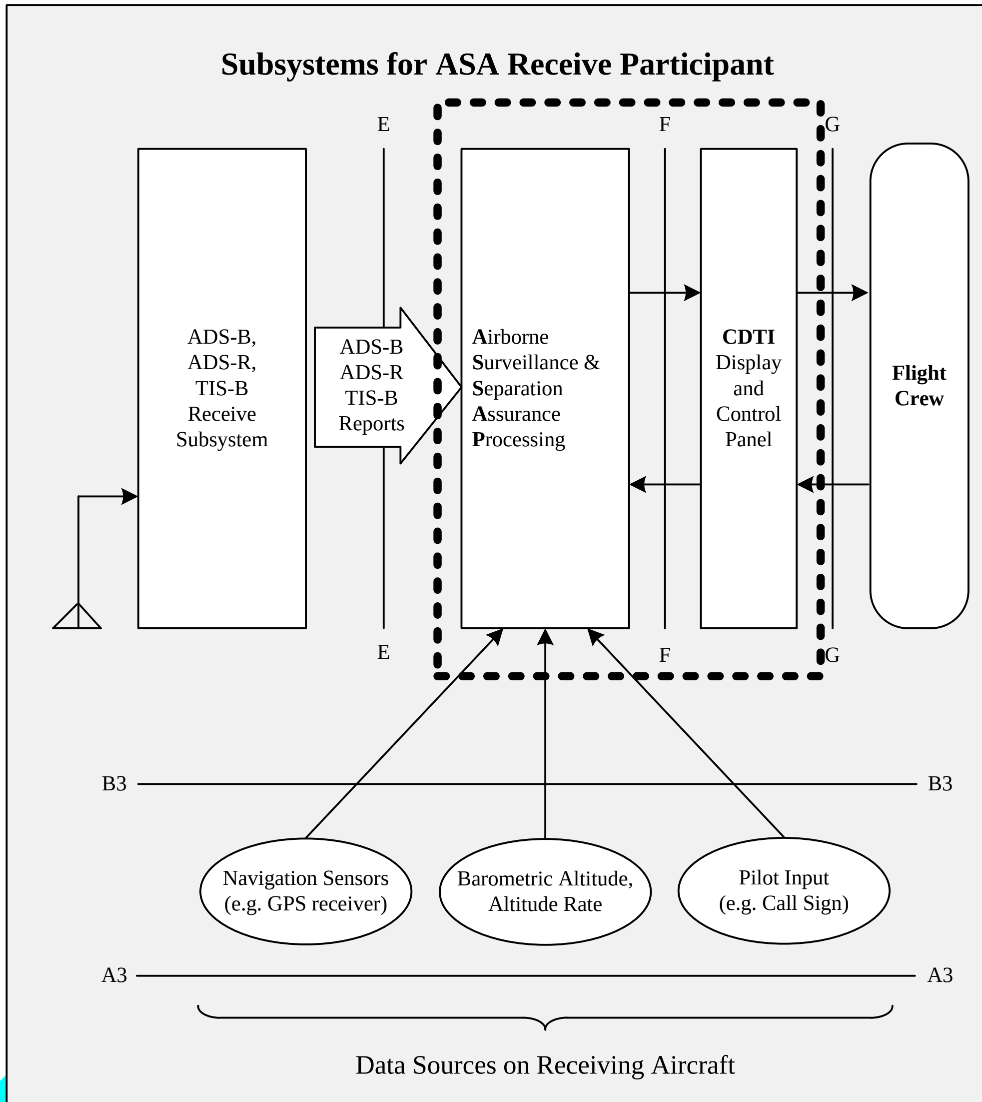
Class C3: Ground ATS Receive-Only ADS-B Subsystems for flight following surveillance is available from this equipage class for use by private operations planning groups or for provision of flight following and SAR.

3.1.2 ASSAP Subsystem Description

The Airborne Surveillance and Separation Assurance Processing (ASSAP) subsystem represents the surveillance and application-specific processing functions of ASA. ASSAP surveillance processing consists of correlation, and track processing of ADS-B, ADS-R, TIS-B, and TCAS (if equipped) traffic reports. ASSAP application processing provides the application-specific processing for all ASA applications. The extent of ASSAP application processing is dependent upon the aircraft's capabilities, as determined by each application's minimum performance requirements. ASSAP application processing may be minimal for airborne situational awareness applications (e.g., EVAcq or AIRB), or may require more significant processing for surface situational awareness applications (e.g., SURF) or future guidance applications (e.g., FIM-S). The ASSAP subsystem also monitors and processes flight crew inputs via the interface from the Cockpit Display of Traffic Information (CDTI) subsystem, and provides all traffic surveillance data and ASA application-specific data for visual and /or aural display to the CDTI for the flight crew.

3.1.2.1 ASSAP/CDTI System Boundaries

Figure 3-7 illustrate the ASSAP/CDTI system boundaries as two subsystems of the ASA System, and is based on Figure 1-1. The dashed line represents the system boundary for the ASSAP and CDTI subsystems. The allocated requirements for ASSAP and the CDTI are found in §3.4.1 and §3.4.2, respectively.



<u>Figure 3-7:</u> ASSAP/CDTI Subsystem Boundaries

<u>Note:</u> *Detailed ASSAP and CDTI performance and subsystem requirements are addressed in the ASA System MOPS, the latest version of RTCA DO-317( ) [49].*

While ASSAP provides all application-specific processing for ASA, it also maintains the interfaces to and from the CDTI. It is due to the close association of the ASSAP and the CDTI, and their shared interface, that the ASSAP and CDTI MOPS was developed as a single requirements document. The two subsystems, ASSAP and CDTI, constitute the “Aircraft Surveillance Application Systems“ and the Minimum Operational Performance Standards document for this system is termed the “ASA System MOPS” the latest version of RTCA DO-317( ) [49].

As shown in Figure 3-7, the CDTI subsystem also serves as the ASA interface to the flight crew.

3.1.3 CDTI Subsystem Description

The CDTI subsystem includes the actual visual and aural display media and the necessary controls to interface with the flight crew. Thus the CDTI consists of all displays and controls necessary to support the applications. The controls may be a dedicated CDTI control panel or it may be incorporated into other controls, (e.g., multifunction control display unit (MCDU) or Electronic Flight Bag (EFB)). Similarly, the CDTI display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB. At a minimum, CDTI includes a graphical plan-view (top down) traffic display (a “Traffic Display”), and the controls for the display and applications (as required). Additional graphical and non-graphical display surfaces may also be included. The CDTI receives position information of traffic and Ownship from the Airborne Surveillance and Separation Assurance processing (ASSAP) subsystem. The ASSAP receives such information from the surveillance sensors and Ownship position sensors.

A physical display screen may have more than one instance of a CDTI Display on it. For example, a display with a split screen that has a Traffic Display on one half of the screen and a list of targets on the other half has two instances of CDTI Displays.

The Traffic Display is a graphical plan-view (top down) traffic display. Every CDTI installation includes a Traffic Display. The Traffic Display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB.

Specific requirements for the Traffic Display are shown in the ASA MOPS. The Traffic Display is required to indicate Ownship position and, to show the positions, relative to the Ownship, of traffic. The Traffic Display is also required to provide specific traffic information elements in associated data tag and traffic symbology.

3.1.4 ANSP Systems

3.1.4.1 ADS-B (Ground Receive)

3.1.4.1.1 ADS-B Non-Radar-Airspace (NRA) Application (ADS-B-NRA)

The ADS-B-NRA application (see Table 2-7) is designed to support and enhance Air Traffic Services in both En- route and Terminal Maneuvering Area (TMA) airspaces in non-radar areas.

The ADS-B-NRA application will provide enhanced Air Traffic Services in areas where radar surveillance currently does not exist.

The ADS-B-NRA application will be most beneficial in areas where, the level of traffic, location, or the cost of the equipment, cannot justify the installation of a radar. Examples of such areas include remote locations, off-shore oil rigs and small island environments. ADS-B-NRA may also be used in areas where an existing radar is to be de-commissioned and the replacement costs cannot be justified.

The ADS-B-NRA application is designed to enhance the following ICAO Air Traffic and Flight Information Services:

- Operation of air traffic control service
- Separation minima
- Transfer of responsibility for control
- Air traffic control clearances
- Scope of flight information service
- Alerting Service, principally for the following functions: Notification of rescue co-ordination centers
- Plotting of aircraft in a state of emergency
- Air Traffic Advisory Services

ADS-B-NRA will provide benefits to capacity and enhancements to these services, when compared to current capabilities, in a way similar to the introduction of SSR radar. This will be especially true when and where many aircraft become ADS-B equipped.

It is expected that this application will provide, efficiency and safety in a similar way as could be achieved by the introduction of SSR radar.

ADS-B-NRA will enhance the Air Traffic Control Service by providing controllers with improved situational awareness of aircraft positions and the possibility of applying separation minima much smaller than what is presently used with current procedures. The Alerting Service will be enhanced by more accurate information on the latest position of aircraft. Furthermore, the broadcast of ADS-B emergency status information will be displayed to the controller independently from any radio communications.

The intention of the ADS-B-NRA application is to allow the procedures using radar surveillance to be enabled by ADS-B, assuming that the quality of service of ADS-B surveillance is similar to (or better than) SSR radar and that appropriate air-ground communications coverage is available.

While the role of the controller and pilot will remain unchanged, there may be impact on their workloads because of new control procedures and the provision of enhanced services. Flight crews may interface with the ADS-B transmitter in a way similar to that of a SSR transponder.

ADS-B-NRA is discussed in more detail in RTCA DO-303, *Safety, Performance and Interoperability Requirements Document for the ADS-B Non-Radar-Airspace (NRA) Application* [46].

3.1.4.1.2 Enhanced Air Traffic Services in Radar-Controlled Areas Using ADS-B Surveillance (ADS-B-RAD)

The ADS-B-RAD application (see Table 2-7) will support, and in some cases enhance, Air Traffic Services through the addition of ADS-B surveillance in areas where radar surveillance exists. It will apply to the En Route and terminal airspace in classes A to D. The application is designed to support the following ICAO Air Traffic Services:

1. Air Traffic Control Service, including
    a. Area Control Service
    b. Approach Control Service
2. Flight Information Service;
3. Alerting Service;
4. Air Traffic Advisory Service.

The introduction of ADS-B may enhance these services by improving the overall quality of surveillance, i.e., radar plus ADS-B such that an operational benefit may include a reduction in the applied separation standards from that applied in today's airspace but not below the ICAO minima, e.g., 10 NM to 5 NM.

Enhanced Air Traffic Services in Radar-Controlled Areas Using ADS-B Surveillance is discussed in more detail in RTCA DO-318, *Safety, Performance and Interoperability Requirements Document for Enhanced Air Traffic Services in Radar-Controlled Areas Using ADS-B Surveillance (ADS-B-RAD)* [50].

3.1.4.1.3 ADS-B Airport Surface Surveillance Application (ADS-B-APT)

The ADS-B-APT application (see Table 2-7) aims to enhance aerodrome operations by adding ADS-B surveillance to a non-surveilled aerodrome and provide the controller with an appropriate graphical display to view the surveillance data.

The ADS-B-APT application will provide the controller with a display of the airport layout (showing as a minimum runway and taxiway boundaries) and the positions of the aircraft and ground vehicles on the Maneuvering Area, along with the surveillance data associated with these vehicles.

ADS-B-NRA surveillance data is intended to augment the controller's situational awareness and help manage the traffic in a more efficient way. The ADS-B-APT application will support the controller in performing the Aerodrome Control Service tasks, for example to assist in the detection of runway incursions. In this respect, the application does not aim to reduce the occurrence of runway incursions, but may reduce the occurrence of runway collisions by assisting in the detection of the incursions.

Controllers use radio communications and out the window scans, as well as manual aide-memoires to obtain and maintain traffic situational awareness in support of the Aerodrome Control Service. As visual observation is the primary source of aircraft and ground vehicle situation awareness, ADS-B-APT is expected to bring its greatest benefits in poor visibility conditions, when visual observation may become difficult and the controller becomes more reliant on voice and other aids.

The most similar existing environment to the ADS-B-APT environment is an environment with a Surface Movement Radar (SMR) in that both are designed as an augmentation to Aerodrome Procedures and not designed to be used on their own (such as for A-SMGCS).

In the Target Environment, all existing procedures for flight crews and controllers used for Aerodrome Operations remain valid and unchanged when compared to the Reference Environment, except transponder procedures which will be required to be applied before entering the Maneuvering Area. Flight crew and controller roles and responsibilities are also unchanged by the introduction of ADS-B-APT. Further, the design of the airport is unchanged with the introduction of ADS-B-APT.

Some data items that ADS-B provides (e.g., identification) are not available in the SMR environment. In this regard, guidance is provided on identification procedures, though there are no new procedures relating to the identification of aircraft or ground vehicles. The controller may correlate the callsign with the Mode A code or use direct recognition of the vehicle's Identity Information in the ADS-B label.

ASSUMP 10: The ADS-B-APT Target Environment is assumed to be a simple to complex aerodrome layout with many taxiways, possibly multiple terminals and aprons and possibly multiple runways, but limited up to two active runways at a time, with ADS-B as a unique means of surveillance. 100% ADS-B OUT qualified equipage for the aircraft or ground vehicles in the Maneuvering Area is assumed.

The ADS-B-APT application is not designed to assist in the detection of Intruders, as they are not authorized and/or not equipped.

ADS-B-APT is discussed in more detail in RTCA DO-321, *Safety, Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT)* [52].

3.1.4.2 TIS-B and ADS-R Service Description

This section defines the Automatic Dependent Surveillance-Rebroadcast (ADS-R) and Traffic Information Broadcast Services (TIS-B) services provided by the FAA Surveillance and Broadcast Services System (SBS – Ground System). Together, ADS-R and TIS-B, provide the ADS-B user pilot's CDTI with aircraft/vehicle (A/V) position data that will compliment and complete the view of neighboring traffic.

ADS-R is an SBS service that receives ADS-B-OUT position broadcasts and rebroadcasts that information to aircraft in the vicinity equipped with a different ADS-B data link. ADS-R service provides for interoperability between ADS-B equipped aircraft with different data links.

TIS-B is a surveillance service that derives traffic information from FAA radar/sensor sources, and uplinks this traffic information to ADS-B-equipped aircraft. TIS-B enables ADS-B-equipped aircraft to receive position reports on non-ADS-B-equipped aircraft in the NAS. TIS-B Service is intended for the transition period to full ADS-B equipage.

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3.1.4.2.1 ADS-R Service

Automatic Dependent Surveillance–Rebroadcast (ADS-R) is a service that relays ADS-B information transmitted by an aircraft using one link technology to aircraft of an incompatible link technology. The Ground System infrastructure monitors ADS-B transmissions by active ADS-B equipped aircraft and continuously monitors the presence of proximate aircraft with incompatible link technologies (e.g., UAT and 1090ES). When such aircraft are in proximity of each other, the Ground System directs ground radio stations within range of both aircraft to rebroadcast surveillance information received on one link frequency to aircraft on the other link frequency. The ADS-R Service currently supports only advisory level surveillance applications.

3.1.4.2.1.1 ADS-R Concept of Operations

Since two incompatible ADS-B link technologies are allowed, aircraft equipped with a single link technology input will not be able to receive ADS-B transmissions from the other link technology, and therefore will be unable to receive all ADS-B transmissions. The ADS-R service closes this gap. In defined airspace regions, the ADS-R service will receive ADS-B transmissions on one link, and retransmit them on the complementary link when there is an aircraft of the complementary link technology in the vicinity.

An aircraft or vehicle that is an active ADS-B user and is receiving ADS-R service is known as an ADS-R Client. An ADS-B equipped aircraft or vehicle on the opposite link of the ADS-R Client that has its messages translated and transmitted by the SBS System is known as an ADS-R Target.

3.1.4.2.1.2 ADS-R Client Identification

In order to receive ADS-R service an aircraft must be in an airspace region where the ADS-R service is offered, must be ADS-B-OUT, must have produced valid position data within the last 30 seconds to a SBS ground station, and must be ADS-B-IN on only one link (if ADS-B-IN on both links, ADS-R is not needed). The SBS – Ground System monitors the received ADS-B Reports to identify active ADS-B users, and the ADS-B-IN link technologies operating on the aircraft.

Note: *With respect to the user aircraft/vehicle (A/V) data links; ADS-B-OUT indicates the A/V can transmit ADS-B Messages, ADS-B-IN indicates the A/V can receive service messages such as ADS-R and TIS-B. A dual data link equipped A/V can transmit and receive both 1090ES and UAT services.*

3.1.4.2.1.3 ADS-R Target Identification

The SBS – Ground System identifies all aircraft that need to receive ADS-R transmissions for each active ADS-B transmitter. It does this by maintaining a list of all active ADS-B users, and their associated input link technologies. For each transmitting ADS-B aircraft the SBS – Ground System determines all aircraft that do not have ADS-B-IN of the same link technology, that are within the vicinity, and need to receive ADS-R transmissions.

3.1.4.2.1.4 ADS-R in Enroute and Terminal Airspace Domains

To determine if a client requires ADS-R service, the SBS – Ground System will examine all candidate proximity aircraft, i.e., aircraft within a 15 NM horizontal range and ±5000 feet altitude of a client aircraft as shown in Figure 3-8. Aircraft that do not have ADS-B-IN of the same link technology as the client, and they are within the cylinder shown in Figure 3-8, are candidate ADS-R targets whose ID, position data, etc are required to be transmitted to the client.

In addition, ADS-B targets in a ground state are not provided to ADS-B-IN airborne clients, i.e., airborne clients within the Enroute or Terminal SVs.

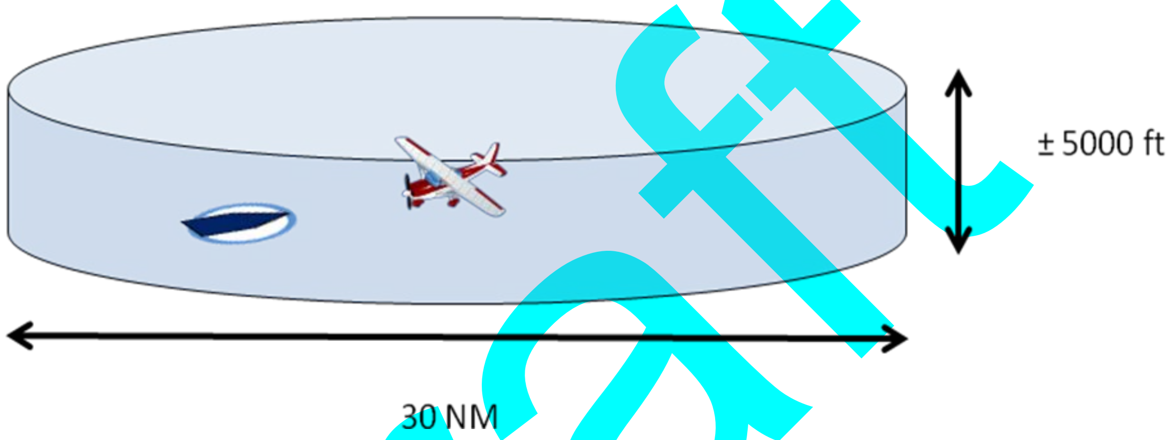

Figure 3-8: ADS-R Client Proximity Determination

3.1.4.2.1.5 ADS-R in Surface Domains

In a surface domain SV, a client is provided all applicable ADS-R targets in the SV domain. This includes all targets in the on-the-ground state within the movement area (runways and taxiways) as well as all airborne targets within 5 NM and 2000 feet AGL of the airport reference point (ARP).

3.1.4.2.1.6 Transmission of ADS-R Targets over the Air Interface

Each ADS-R Target aircraft may have one or more client aircraft that need to receive ADS-R transmissions, possibly in different domains. The SBS – Ground System determines the ADS-R transmission rate required by the client in the most demanding domain.

A client aircraft that is receiving ADS-R service will receive reports for ADS-B aircraft on the opposite link within its vicinity. Since a single target may have multiple clients, sometimes in different domains, a client may receive ADS-R reports more frequently than required for the client's domain. An aircraft may also be in range of a ground radio station that is transmitting reports required by other aircraft. When this is the case the client aircraft will receive reports of aircraft that are outside the altitude and horizontal range of its vicinity.

3.1.4.2.2 TIS-B Service

3.1.4.2.2.1 TIS-B Service Concept of Operations

The TIS-B service provides active ADS-B users with a low-latency stream of position reports of non-ADS-B equipped aircraft. TIS-B service is available in supported Service Volumes when there is both adequate surveillance coverage from non-ADS-B ground sensors and adequate Radio Frequency (RF) coverage from SBS – Ground System radio stations.

An aircraft or vehicle that is an active ADS-B user and is receiving TIS-B service is known as a TIS-B Client. A non-ADS-B equipped aircraft or vehicle that has its position transmitted in TIS-B reports is known as a TIS-B Target.

3.1.4.2.2.2 TIS-B Client Identification

The SBS – Ground System monitors the ADS-B received reports to identify TIS-B Client aircraft. In order to be considered a TIS-B Client, an aircraft must be ADS-B-OUT, must have produced valid position data within the last 30 seconds to a SBS ground station, must be under surveillance of at least one secondary radar and must be ADS-B-IN on at least one link. The TIS-B Service Status message is provided to UAT clients to indicate TIS-B service availability; this is considered to be a key safety benefit.

The SBS – Ground System monitors the received ADS-B Reports to identify active ADS-B users, and the ADS-B-IN link technologies operating on the aircraft.

Note: *With respect to the user aircraft/vehicle (A/V) data links; ADS-B-OUT indicates the A/V can transmit ADS-B Messages, ADS-B-IN indicates the A/V can receive service messages such as ADS-R and TIS-B. A dual data link equipped A/V can transmit and receive both 1090ES and UAT services.*

3.1.4.2.2.3 TIS-B Target Identification

The SBS – Ground System monitors surveillance information from the FAA. The surveillance data is correlated and merged from multiple surveillance sources into individual aircraft tracks. Aircraft tracks that cannot be correlated with an active ADS-B user track are potential TIS-B Targets.

Each ATCRBS and Mode S aircraft track identified by the tracker is assigned a unique ID when a 24-Bit address is unavailable for that target. When an ICAO address is available for a Mode S track (typically only in the surface service volumes), then this address is provided in the TIS-B messages. The SBS – Ground System has multiple trackers, deployed regionally such that there is an airborne tracker dedicated to the airspace of each FAA Enroute Center/Terminal Area. There is no correlation of track IDs between trackers, so as a TIS-B Target transitions across Service Volume boundaries between Enroute Centers, its Track ID will change, which may cause duplicate symbols to overlap while the old track ID times out on a CDTI. The avionics may need to be aware of the potential for track ID changes and perform correlation and association processing to associate aircraft across the track ID change in order to minimize duplicate symbols and perception of dropped tracks.

When ADS-R services are not offered in an airspace, the TIS-B service provides Client ADS-B equipped aircraft with proximity targets that are ADS-B equipped on the opposite link technology.

3.1.4.2.2.4 TIS-B in Enroute and Terminal Airspace Domains

The SBS – Ground System examines each potential TIS-B target to determine if it is within proximity of one or more TIS-B clients. In order to become a TIS-B target, a potential target must be contained in a cylinder defined by lateral and vertical distance from Client aircraft. The size of this cylinder depends on the airspace domain of the Client aircraft. TIS-B Service is provided to aircraft operating in the En Route and Terminal Service Volumes. There is a Service Ceiling of 24000 feet, above which TIS-B clients will not be provided TIS-B service.

In the En Route and Terminal domains, proximity aircraft include all aircraft within a 15 NM radius and ±3500 feet of altitude. Aircraft or vehicles determined to be operating on the surface will not be considered valid TIS-B targets for aircraft operating in En Route and Terminal Service Volumes.

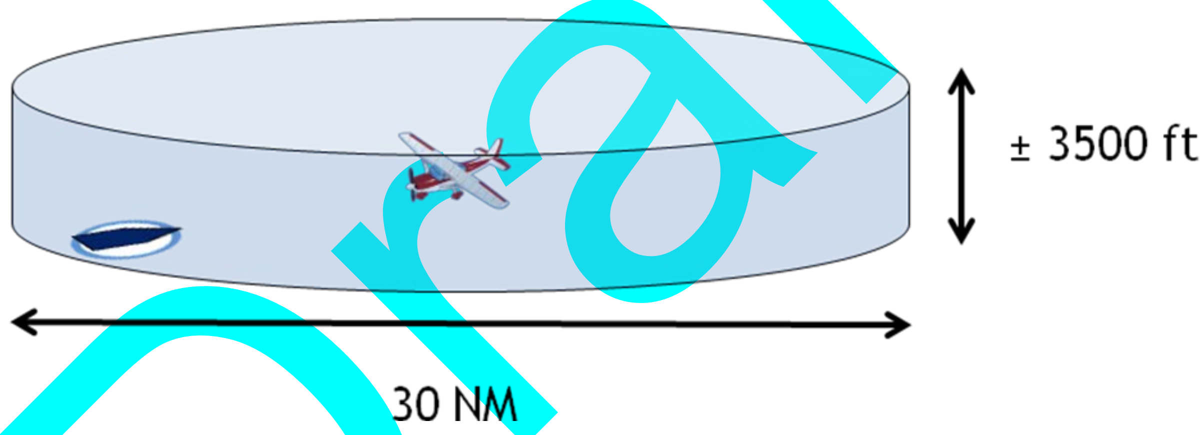

Figure 3-9: TIS-B Client Proximity Determination

3.1.4.2.2.5 TIS-B in Surface Domains

In a surface domain SV, a client is provided all applicable TIS-B targets in SV domain. This includes all targets in the on-the-ground state within the movement area as well as airborne targets within 5 NM and 2000 feet AGL of the airport reference point (ARP). Additionally, TIS-B in surface domains covers expanding volumes along the approach and departure corridors.

3.1.4.2.2.6 Transmission of TIS-B Target Messages

The SBS – Ground System transmits TIS-B reports for every TIS-B Target that is in proximity of one or more Clients. An individual Target may be in proximity of multiple Clients, with the potential for the Clients to be in separate airspace domains, with differing update rates. The SBS – Ground System will transmit TIS-B reports for a

Target aircraft at the highest rate required by any of the clients of that aircraft. For example, if a Target aircraft has clients in both terminal and en route domains, TIS-B reports for that Target aircraft will be transmitted at the rate required for the terminal domain.

3.1.4.3 TIS-B and ADS-R Subsystem Requirements

{information in this section was derived from the FAA SBS Program Office Surveillance and Broadcast Services Description Document, SRT-047, Revision 01, October 24, 2011}

3.1.4.3.1 TIS-B Service Messages and Performance Requirements

The TIS-B Service provides users equipped with ADS-B Out and ADS-B In avionics the ability to receive, process, and display state information on proximate traffic that are not ADS-B equipped and are only tracked by other ground-based surveillance systems (i.e., radar and multilateration systems). The performance that is required in delivering the TIS-B Service is detailed in following paragraphs.

3.1.4.3.1.1 TIS-B Quality of Service

The TIS-B Service **shall (R3.001)** {new reqmt} support several Surveillance and Broadcast Services applications identified in the SBS CONOPS, including:

- Traffic Situation Awareness – Basic (12.1 seconds)
- Airport Traffic Situation Awareness (2 seconds)
- Airport Traffic Situation Awareness with Indications and Alerts (2 seconds)

The TIS-B/ADS-R Service Status message **shall (R3.002)** {new reqmt} be broadcast such that each client will receive this message with their 24-bit address with an update interval of 20 seconds (95%).

The TIS-B/ADS-R Service Status message **shall (R3.003)** {new reqmt} only be provided to clients that are eligible for both TIS-B and ADS-R service.

Notes:

1. *An aircraft or vehicle that is an active ADS-B user and is receiving ADS-R service is known as an ADS-R Client.*
2. *TIS-B is deployed as a client-oriented service and provides near-by traffic information to ADS-B equipped aircraft. TIS-B service area is a cylinder centered on the client. TIS-clients are determined based on the set of ADS-B Reports received by the SBSS Radio Stations.*

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3.1.4.3.1.1.1 TIS-B Integrity and Accuracy

The probability that TIS-B Service introduces any error into a TIS-B Message **shall (R3.004)** {new reqmt} be less than or equal to 10^{-5} per Message (equivalent to a System Design Assurance level of 2 – Major). This probability of error includes the linear position extrapolation process using the instantaneous velocity reported for a target.

The Source Integrity Level (SIL) is a SBS system-wide configured value that **shall (R3.005)** {new reqmt} be provided by TIS-B service.

The Navigation Integrity Category (NIC) **shall (R3.006)** {new reqmt} be computed for TIS-B messages based on the configured SIL value, the target's NAC_P (described below), and the containment error 'tail' based on radar plot error measurements and specified performance values. Radar PARROTs and Certification Targets will be monitored for faults and excessive biases such that the sensors are not used when a fault is detected.

The SIL Supplement **shall (R3.007)** {new reqmt} be encoded as 1 to indicate that the probability of a TIS-B target exceeding the NIC containment radius is calculated on a per sample basis.

TIS-B reports **shall (R3.008)** {new reqmt} be sent with a NAC_V. The NAC_V will typically be 0 unless a value greater than or equal to ONE (1) can be calculated from the supporting sensors.

The TIS-B Service **shall (R3.009)** {new reqmt} reference a target's barometric pressure altitude to standard temperature and pressure.

The TIS-B Service **shall (R3.010)** {new reqmt} compute a NAC_P for each target at each track state vector update. For the applications supported by TIS-B, Navigation Accuracy Category - Position (NAC_P) is limited to the horizontal position information. NAC_P for a TIS-B target is based on the surveillance sources used to derive the target position rather than navigation sources used to supply ADS-B position. Therefore, the derivation of NACP for TIS-B is different from that for ADS-B. For example, the NAC_P value must include the uncertainty in converting slant range measurements to horizontal position estimates.

TIS-B Track angle and position accuracy for surface targets **shall (R3.011)** {new reqmt} be provided by TIS-B service.

The TIS-B Service **shall (R3.012)** {new reqmt} set the Track Angle to Invalid when the target ground speed drops below a defined threshold (currently set to 11.84 Knots)

In En Route and Terminal environments the track accuracy **shall (R3.013)** {new reqmt} meet or exceed the values shown in Table 3-2.

Table 3-2: Requirements for Track Accuracy

Central Sensor	Flight Path	Speed (kts)	Rng. (NM)	Position Error (NM)		Heading Error (°)		Speed Error (kts)	
				Peak RMS Position Error	Mean Position Error	Peak RMS Heading Error	Mean RMS Heading Error	Peak RMS Speed error	Mean RMS Speed error
Short Range Sensor (ATCBI-5)	Linear Acceleration†	650->250->650	Center	0.4		13		37	
			All	0.6		19		60	
	180°	100	48 (case 3)	0.4(0.4+)		97 (70+)		20 (10+)	
		250-700		0.4(0.4+)		32 (30+)		20 (10+)	
	Radial	100	50*** (case 2)		0.1 (0.1#)		7 (2#)		5 (4#)
	Tangential	100			0.1 (0.1#)		5 (5#)		9 (7#)
Long Range Sensor (ATCBI-5)	Linear Acceleration†	650->250->650	n/a	0.5		13		60	
	90° turn	100-400	84 (case 2)	1.1 (0.4+)		70 (38+)		60+	
		700***		1.8 (0.4+)		34 (14+)		54 (14+)	
	Radial	100-700	100		0.5				11
	Tangential	100-700	80		0.4		7		15

Notes:

1. *Table symbology:*

† *These scenarios were generated and the values in this table are based on best engineering judgment.*

\+ *These multisensor cases use existing scenarios (because they are not spatially distributed).*

\# *These multisensor cases use a single target path from existing scenarios and are run multiple times through the standalone filter algorithm, with independent noise generated each time (i.e., run Monte Carlo iterations).*

3.1.4.3.1.1.2 TIS-B Position Update Interval

The TIS-B Service updates target position and velocity data based on surveillance measurement events and is therefore dependent on the availability of source sensors for new data. The following specifications apply only when sensor data is available to the TIS-B Service to support the performance requirements. Under lightly-loaded conditions the TIS-B service may transmit reports at a rate higher than the minimum specified rate. Graceful Degradation algorithms are implemented which will throttle transmissions back to the required update rate as the system becomes more loaded. Sometimes it will be necessary to transmit the same report multiple times in order to ensure the required update rate and probability of detection.

The maximum message transmission rate for a TIS-B Target to a 1090 and UAT clients **shall (R3.014)** {new reqmt} be 1 time per second (this is the expected rate for targets in Surface Service volumes where ASDE-X sends track updates at approximately 1 Hz).

3.1.4.3.1.1.3 Surface Update Interval

The TIS-B Service **shall (R3.015)** {new reqmt} transmit the number of TIS-B Messages necessary to meet an update interval of no greater than 2 seconds (95%) for each client aircraft for all traffic within 5 NM and within ±2000 feet of each client within the Surface Service Volume.

3.1.4.3.1.1.4 Terminal Update Interval

The TIS-B Service **shall (R3.016)** {new reqmt} transmit the number of TIS-B Messages necessary to meet an update interval of no greater than 6 seconds (95%) for each client aircraft for all traffic within 15 NM and within ±3500 feet of each client within the Terminal Service Volume.

Airborne TIS-B targets in a Surface SV **shall (R3.017)** {new reqmt} also be provided to clients in a terminal SV.

Ground state TIS-B targets **shall (R3.018) not** {new reqmt} be provided to clients in terminal SV.

3.1.4.3.1.1.5 En-Route Update Interval

The TIS-B Service **shall (R3.019)** {new reqmt} transmit the number of TIS-B Messages necessary to meet an update interval of no greater than 12.1 seconds (95%) for each client aircraft for all traffic within 15 NM and within ±3500 feet of each client within the En-Route Service Volume.

3.1.4.3.1.1.6 TIS-B Service Availability

The TIS-B service is a safety-essential service as classified by NAS-SR-1000A for surveillance services. The availability of the TIS-B Service specified in this section is limited to the SBS system. It includes the ADS-B Receive Function, but does not include FAA surveillance sensors providing sensor data. The TIS-B Service **shall (R3.020)** {new reqmt} meet a minimum Availability of 0.999 for the TIS-B Clients.

3.1.4.3.1.1.7 TIS-B Media Access

TIS-B transmissions **shall (R3.021)** {new reqmt} be transmitted in a manner that is compatible with the transmit protocol of the ADS-B data link. For example, TIS-B transmissions contend with air-to-air ADS-B transmissions and potentially with nearby SBS Ground Station transmissions. TIS-B transmissions should be transmitted to minimize potential interference on the data link.

Although TIS-B transmissions are event-driven by receptions of radar/Airport Surface Surveillance Capability (ASSC) System updates, transmission times have configurable

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minimum TIS-B transmit intervals (nominally set to 2 ms) with an added random time (up to nominally 3 milliseconds) appended to the minimum interval. Additionally, typically only one Ground Station uplinks a particular target at any given time.

Note: *These transmit parameters are set in consideration of maximum capacity, update interval, and interference environment requirements for each Ground Station.*

3.1.4.3.2 ADS-R Service Messages and Performance

The ADS-R Service is dependent upon the ADS-B Service, in that the ADS-B Messages are first received on one data link before they can be rebroadcast on the other. The performance that is required in delivering the ADS-R Service is detailed in following paragraphs.

3.1.4.3.2.1 ADS-R Quality of Service

3.1.4.3.2.1.1 ADS-R Integrity and Accuracy

The probability that ADS-R Service introduces any error into a rebroadcast ADS-B Message **shall (R3.022)** {new reqmt} be less than or equal to 10^{-5} per Message (equivalent to a System Design Assurance level of 2 – Major). This probability of error includes the linear position extrapolation process using the instantaneous velocity reported for a target on the opposite ADS-B data link.

3.1.4.3.2.1.2 ADS-R Position Update Interval

The ADS-R Service **shall (R3.023)** {new reqmt} broadcast state vector updates for aircraft/vehicles transmitting on one data link to aircraft/vehicles on the other data link at an interval that will support the aircraft/vehicle based applications that are to be performed in the Service Volume. The state vector update intervals required to support each application are detailed in the SBS CONOPS and summarized as follows:

- Traffic Situation Awareness – Basic (12.1 seconds)
- Airport Traffic Situation Awareness (2 seconds)
- Airport Traffic Situation Awareness with Indications and Alerts (2 seconds)
- Traffic Situation Awareness for Visual Approach (5 seconds)
- Traffic Situation Awareness with Alerts (10 seconds)
- Flight-Deck Based Interval Management–Spacing (10 seconds)

The ADS-R update interval requirements are based upon the most stringent application that is to be supported within each domain. The update intervals apply to the reception by a client aircraft of all eligible ADS-R aircraft/vehicles within the range and altitude limits at any point within the Service Volume.

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Note: *The ADS-R update interval is limited by the ADS-B Message reception rate from each aircraft/vehicle (as rebroadcasts may be made only when Messages are received), and the performance characteristics of the aircraft/vehicle ADS-B equipment.*

As the system becomes loaded with more than 250 ADS-R targets on each link, these target message transmission rates **shall (R3.024)** {new reqmt} decrease in a process known as Graceful Degradation. The purpose of Graceful Degradation (GD) is to gradually throttle the ADS-R messages sent to Aircraft/Vehicles based on load. The GD algorithm uses several configurable parameters to control the flow of reports and messages until the maximum load is reached. As the Ground Station nears its configured target capacity, the per-target minimum transmit interval increases gradually until reaching a minimum rate of transmission for each target to support the service volume update interval.

3.1.4.3.2.1.3 Surface Update Interval

The ADS-R Service **shall (R3.025)** {new reqmt} transmit the number of ADS-R Messages necessary to meet an update interval of no greater than 2 seconds (95%) for each client aircraft for all traffic within 5 NM and within ±2000 feet of each client within the Surface Service Volume.

3.1.4.3.2.1.4 Terminal Update Interval

The ADS-R Service **shall (R3.026)** {new reqmt} transmit the number of ADS-R Messages necessary to meet an update interval of no greater than 5 seconds (95%) for each client aircraft for all traffic within 15 NM and within ±5000 feet of each client within the Terminal Service Volume.

3.1.4.3.2.1.5 En-Route Update Interval

The ADS-R Service **shall (R3.027)** {new reqmt} transmit the number of ADS-R Messages necessary to meet an update interval of no greater than 10 seconds (95%) for each client aircraft for all traffic within 15 NM and within ±5000 feet of each client within the En-Route Service Volume.

3.1.4.3.2.1.6 ADS-R Service Availability

The ADS-R service is currently a safety-essential service as classified by NAS-SR-1000A for surveillance services. The ADS-R Service **shall (R3.028)** {new reqmt} meet a minimum Availability of 0.999 for client aircraft that are receiving ADS-R.

Note: *The ADS-R service should be capable of being enhanced to meet a minimum availability of 0.99999 for Safety Critical applications.*

3.1.5 Surface Vehicles

Surface vehicles include those that tow and service aircraft, load cargo and transport passengers, and emergency vehicles. ADS-B enables properly equipped ground vehicles to broadcast their state vector, horizontal and vertical position, horizontal and vertical velocity, and other information. These ADS-B Message broadcasts are received by aircraft in the vicinity and by ground surveillance systems, including those that directly use the ADS-B information content and those that use multilateration techniques to derive position. Aircraft equipped with the proper equipment receive the ADS-B Messages, process and display the information for use in air-to-air applications, air-to-ground applications, and ground-to-ground applications.

The vehicle ADS-B transmitting systems are intended to support the following ADS-B applications:

- Air Traffic Control (ATC) Surveillance for Airport Situational Awareness
- Airport Traffic Situational Awareness
- Airport Traffic Situational Awareness with Indications and Alerts

Surface vehicles, because of spectrum restrictions, are generally limited to transmitting while in the airport movement area. The surface vehicle transmit power is reduced from aircraft equipage class transmit requirements because surface coverage area reduces the maximum operating range. However, it is necessary to provide a minimum range of 5 NM to be detected and tracked by aircraft on approach to the airport. Surface vehicles are defined by the equipage Class B2 (see §3.1.1.3.2). If ADS-B link technologies support the use of lower power than the link requires for the minimum B2 equipage class, there needs to be an indication of this in the Mode Status information so that ADS-B receivers can identify these lower power vehicles. Position accuracy requirements for surface vehicles will typically be more demanding on surface vehicle ADS-B transmitters in order to support potential future surface applications.

3.2 Broadcast Information Elements Requirements

The ADS-B system **shall (R3.029)** {from 242AR2.3} be capable of transmitting messages and issuing reports containing the information specified in the following subsections. These MASPS do not specify a particular message structure or encoding technique. The information specified in the following subparagraphs can be sent in one or more messages in order to meet the report update requirements specified in Section §3.4.3.3.

3.2.1 Time of Applicability (TOA)

The Time of Applicability (TOA) of ADS-B Reports indicates the time at which the reported values were valid. Time of Applicability **shall (R3.030)** {from 242AR2.4} be provided in all reports. Requirements on the accuracy of the Time of Applicability are addressed in Section §3.4.3.3.1.1 and paraphrased in §3.5.1.3.3.

Note: *The required resolution of the Time of Applicability value is a function of the Report Type.*

3.2.2 Identification

The basic identification information to be conveyed by ADS-B **shall (R3.031)** {from 242AR2.5} include the following elements:

- Call Sign / Flight ID (§3.2.2.1)
- Participant Address (§3.2.2.2.1) and Address Qualifier (§3.2.2.2.2)
- ADS-B Emitter Category (§3.2.2.3)
- Mode 3/A Code (§3.2.2.4)

3.2.2.1 Call Sign / Flight ID

ADS-B **shall (R3.032)** {from 242AR2.6} be able to convey an aircraft Call Sign or Flight ID of up to 8 alphanumeric characters in length. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Note: *The call sign is reported in the Mode Status (MS) report (§3.5.1.4 and §3.5.1.4.4).*

3.2.2.2 Participant Address and Address Qualifier

The ADS-B system design **shall (R3.033)** {from 242AR2.7} include a means (e.g., an address) to (a), correlate all ADS-B Messages transmitted from the A/V and (b), differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services may be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address **shall (R3.034)** {from 242AR2.8} use the same 24 bit address for ADS-B. All aircraft/vehicle addresses **shall (R3.035)** {from 242AR2.9} be unique within the applicable operational domain(s).

The ADS-B system design **shall (R3.036)** {from 242AR2.10} accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.

Notes:

1. *Some flight operations do not require one to fully disclose either the A/V call sign or address. This feature is provided to encourage voluntary equipage and operation of ADS-B by ensuring that ADS-B Messages will not be traceable to an aircraft if the operator requires anonymity.*

2. *Correlation of ADS-B Messages with Mode S transponder codes will facilitate the integration of radar and ADS-B information on the same aircraft during transition.*

3. *The TIS-B Service in the EnRoute and Terminal service volumes may use a Track ID value, rather than the ICAO 24-bit Address.*

3.2.2.2.1 Participant Address

The Participant Address field **shall (R3.037)** {from 242AR2.11} be included in all ADS-B Reports. This 24-bit field contains either the ICAO 24-bit address assigned to the particular aircraft about which the report is concerned, or another kind of address that is unique within the operational domain, as determined by the Address Qualifier field.

The ADS-B subsystem provides a means for identification of ADS-B participants transmitting on an ADS-B data link. The use of the ICAO 24-bit address provides global identification of ADS-B participants but other address types can be utilized as provided by the Address Qualifier field (§3.2.2.2.2). Although the use of assigned ICAO 24-bit addresses is coordinated globally to insure uniqueness, there is no guarantee that duplicate addresses may not occur. ADS-B data links need provisions to protect against correlating the wrong data to an ADS-B participant or failing to detect multiple targets transmitting using the same ICAO 24-bit address. ADS-B data links that convey partial data elements relying on the ICAO 24-bit address to correlate received messages to ADS-B tracks are especially vulnerable. Each ADS-B data link **shall (R3.038)** {new reqmt} provide the capability for applications to detect duplicate ICAO 24-bit addresses.

If ADS-B receiver subsystems can not properly correlate received message contents to a single ICAO address among targets transmitting a duplicate address, the receiver **shall (R3.039)** {new reqmt} flag all such data associated with duplicate addresses as invalid.

3.2.2.2.2 Address Qualifier

The Address Qualifier field **shall (R3.040)** {from 242AR2.12} be included in all ADS-B Reports. This field describes whether or not the Address field contains the 24-bit ICAO address of a particular aircraft, or another kind of address that is unique within the operational domain.

Notes:

1. *The particular encoding used for the Address Qualifier is not specified in these MASPS, but is left for specification in lower level documents, such as the MOPS for a particular ADS-B data link.*

2. *Surface vehicles for a given airport need to have unique addresses only within range of the airport; vehicle addresses may be reused at other airports.*

3. *A participant’s address and address qualifier are included as parts of all reports about that participant.*

3.2.2.3 ADS-B Emitter Category

An ADS-B participant's "emitter category" is conveyed in the Mode Status Report (§3.5.1.4 and §3.5.1.4.5). The emitter category describes the type of A/V or other ADS-B participant. The ADS-B system **shall (R3.041)** {from 242AR2.13} provide for at least the following emitter categories:

- Light (ICAO) – 7000 kg (15500 lbs) or less
- Small aircraft – 7000 kg to 34000 kg (15500 lbs to 75000 lbs)
- Large aircraft – 34000 kg to 136000 kg (75000 lbs to 300000 lbs)
- High vortex large (aircraft such as B-757)
- Heavy aircraft (ICAO) – 136000 kg (300000 lbs) or more
- Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise)
- Rotorcraft
- Glider/Sailplane
- Lighter-than-air
- Unmanned Aerial vehicle
- Space/Trans-atmospheric vehicle
- Ultralight / Hang glider / Paraglider
- Parachutist/Skydiver
- Surface Vehicle – emergency vehicle
- Surface Vehicle – service vehicle
- Point obstacle (includes tethered balloons)
- Cluster obstacle
- Line obstacle

Notes:

1. *ICAO Medium aircraft – 7000 to 136000 kg (15500 to 300000 lbs) can be represented as either small or large aircraft as defined above.*

2. *Obstacles can be either fixed or movable. Movable obstacles would require a position source.*

3. *Weights given for determining participant categories are maximum gross weights, not operating weights.*

3.2.2.4 Mode 3/A Code

Since the Mode 3/A code is utilized by many Ground ATC systems for aircraft identification, it may continue to be necessary for ADS-B participants in certain airspace to transmit the Mode 3/A code. ADS-B Transmitting Subsystems **shall (R3.042)** {new reqmt} have the capability to transmit the Mode 3/A code. ADS-B Transmitting Subsystems **shall (R3.043)** {new reqmt} have the capability to disable the transmissions of the Mode 3/A code.

Note: *The broadcast of the Mode 3/A (4096) code is provided as a transitional feature to aid operation of ATC automation systems that use Mode A Code for Flight Plan correlation. The requirement for the broadcast of the Mode 3/A code may be removed from future versions of these MASPS.*

3.2.3 A/V Length and Width Codes

The A/V Length and Width codes (see Table 3-3) describe the amount of space that an aircraft or ground vehicle occupies and are components of the Mode Status report (§3.5.1.4, §3.5.1.4.6). The aircraft length and width codes are not required to be transmitted by all ADS-B participants all of the time. However, they *are* required (§3.5.1.4.6) to be transmitted by aircraft above a certain size, at least while those aircraft are in the airport surface movement area.

3.2.4 Position

Position information **shall (R3.044)** {from 242AR2.14} be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, geometric height, and barometric pressure altitude. The position report elements may be further categorized as geometric position and barometric altitude.

- The geometric position report elements are horizontal position (latitude and longitude), and geometric height. All geometric position elements **shall (R3.045)** {from 242AR2.15} be referenced to the WGS-84 ellipsoid.
- Barometric pressure altitude **shall (R3.046)** {from 242AR2.16} be reported referenced to standard temperature and pressure.

If the GPS Antenna Offset (§3.2.33) is compensated to be the position of the ADS-B participant's ADS-B Position Reference Point (see §3.2.4.1), by setting the encoding to binary "00001" (as indicated in Table 3-28), then the position that is broadcast in ADS-B Messages as that participant's nominal position **shall (R3.047)** {from 242AR2.17} be the position of that participant's ADS-B Position Reference Point (§3.2.4.1).

If the GPS Antenna Offset (§3.2.33) is NOT compensated to be the position of the ADS-B participant's ADS-B Position Reference Point (see §3.2.4.1), then the position that is broadcast in ADS-B Messages is NOT corrected from the position as given by the participant's navigation sensor to the position of that participant's ADS-B Position Reference Point.

> ***Note:*** *Surface movement and runway incursion applications will require high NAC_P values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§3.2.4.1) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B Position Reference Point.*

3.2.4.1 ADS-B Position Reference Point

The nominal location of a transmitting ADS-B participant – the position that is reported to user applications in SV Reports about that participant – is the location of the participant's ***ADS-B Position Reference Point***.

> ***Note 1:*** *An indication is contained in the GPS Antenna Offset (§3.2.33) parameter encoding (MS Report element #10d) as to whether a transmitting ADS-B participant has corrected the position given by its navigation sensor (e.g., the position of the antenna of a GNSS receiver) to the location of its ADS-B Position Reference Point. (The process of correcting the position to that of the Position Reference Point need not be done in the ADS-B Transmitting Subsystem; it might be applied in the navigation sensor, or in another device external to the ADS-B Transmitting Subsystem.) See the description of the GPS Antenna Offset (§3.2.33) parameter encoding to enable applications to calculate the required correction.*

The ***ADS-B Position Reference Point*** of an A/V **shall (R3.048)** {from 242AR2.18} be defined as the center of a rectangle (the "defining rectangle for position reference point") that has the following properties:

a. The defining rectangle for position reference point **shall (R3.049)** {from 242AR2.18-A} have length and width as defined in Table 3-3 below for the length and width codes that the participant is transmitting in messages to support the MS Report.

b. The defining rectangle for position reference point **shall (R3.050)** {from 242AR2.18-B} be aligned parallel to the A/V's heading.

c. The ADS-B position reference point (the center of the defining rectangle for position reference point) **shall (R3.051)** {from 242AR2.18-C} lie along the axis of symmetry of the A/V. (For an asymmetrical A/V, the center of the rectangle should lie midway between the maximum port and starboard extremities of the A/V.)

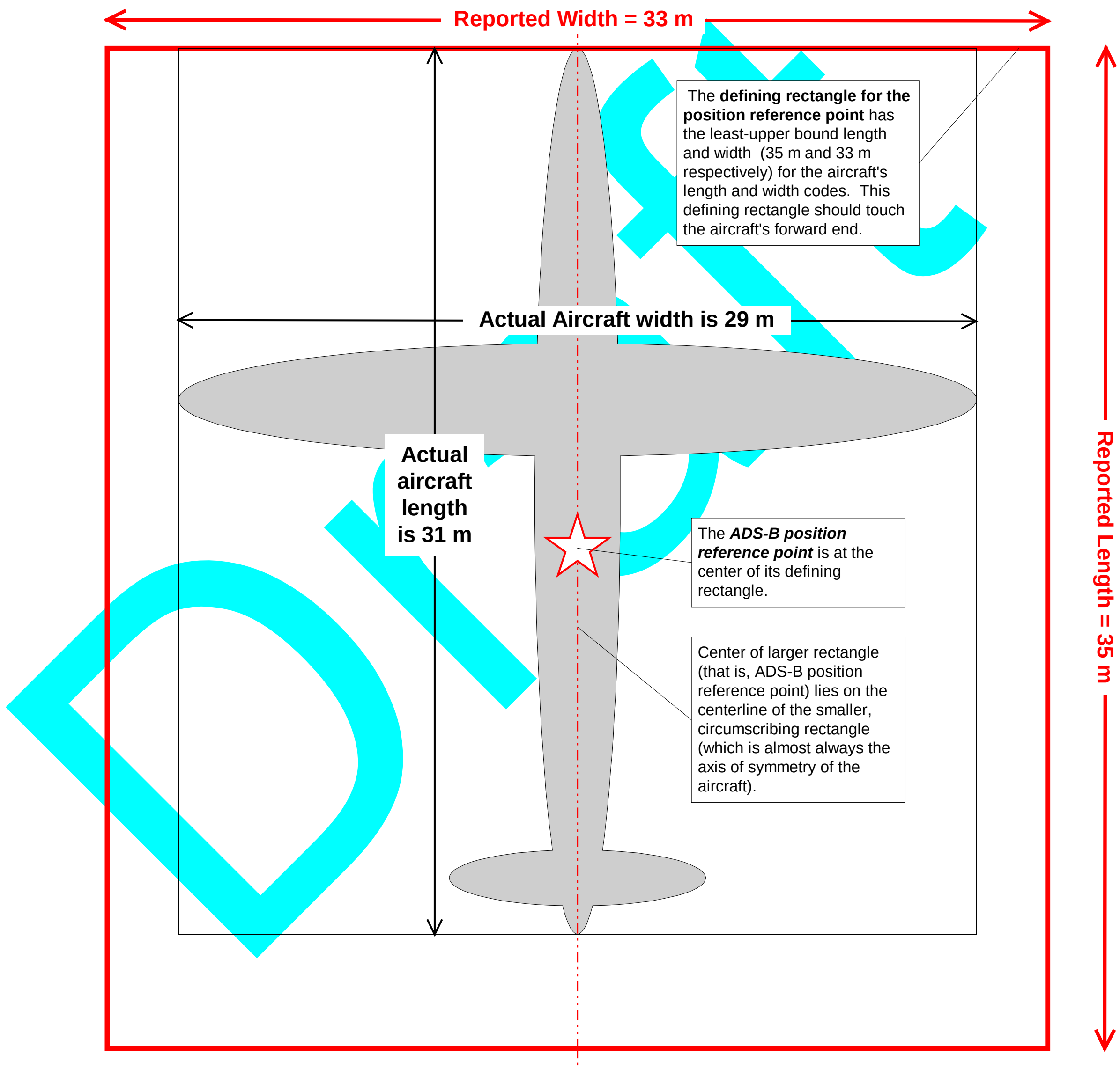
d. The forward extremity of the A/V **shall (R3.052)** {from 242AR2.18-D} just touch the forward end of the defining rectangle for position reference point.

<u>Table 3-3:</u> Dimensions of Defining Rectangle for Position Reference Point.

A/V – L/W Code (Decimal)	Length Code (binary)			Width Code (binary)	Upper-Bound Length and Width for Each Length/Width Code	
					Length (meters)	Width (meters)
0	0	0	0	0	No Data or Unknown	
1	0	0	0	1	15	23
2	0	0	1	0	25	28.5
3				1		34
4	0	1	0	0	35	33
5				1		38
6	0	1	1	0	45	39.5
7				1		45
8	1	0	0	0	55	45
9				1		52
10	1	0	1	0	65	59.5
11				1		67
12	1	1	0	0	75	72.5
13				1		80
14	1	1	1	0	85	80
15				1		90

<u>Note 2:</u> *The lengths and widths given in Table 3-3 are least upper bounds for the possible lengths and widths of an aircraft that reports the given Length and Width code (§3.5.1.4.6). An exception, however, is made for the largest length and width codes, since there is no upper bound for the size of an aircraft that broadcasts those largest length and width codes.*

Figure 3-10 illustrates the location of the ADS-B Position Reference Point, for an example aircraft of length 31 m and width 29 m. Such an aircraft will have length code 2 (L < 35 m) and width code 0 (W < 33m). The ADS-B Position Reference Point is then the center of a rectangle that is 35 m long and 33 m wide and positioned as given in the requirements just stated. This is the position that a transmitting ADS-B participant broadcasts when the transmitted position is adjusted to correct for the position offset between the GPS antenna and the ADS-B Position Reference Point. Alternatively, if the position is not compensated, an ADS-B application can use the transmitted GPS Antenna Offset (§3.2.33) to calculate the position of the ADS-B Position Reference Point.



<u>Figure 3-10:</u> Position Reference Point Definition.

<u>Note 3:</u> *When on the surface, the ability to correct for inaccuracies because of offsets in position between the navigation sensor and the ADS-B Position Reference Point must be provided. If the navigation sensor or the transmitting ADS-B* *participant does not correct for this offset, the lateral distance from the lateral axis of the aircraft and the longitudinal distance from the nose of the aircraft must be conveyed so that the ADS-B application can account for this offset. A means to indicate that the position is corrected to the ADS-B Position Reference Point is provided in the GPS Antenna Offset parameter (§3.2.33).*

Note 4: *There are operational applications where the ADS-B position being reported needs to be related to the extremities of large aircraft; such as, runway incursion alerting and other future surface applications. Therefore, for the aircraft size codes and NAC_p codes defined, the position being broadcast must be translated to a common reference point on the aircraft. The translation calculation on position sensor source data may be performed outside of the ADS-B Transmitting Subsystem, therefore, specific requirements for this function are not defined in these MASPS.*

3.2.4.2 Altitude

Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) **shall (R3.053)** {from 242AR2.19} be provided, if available, to the ADS-B Transmitting Subsystem. Some applications may have to compensate if only one source is available. However, when an A/V is operating on the airport surface, the altitude is not required to be reported, provided that the A/V indicates that it is on the surface.

Altitude **shall (R3.054)** {from 242AR2.20} be provided with a range from -1000 feet up to +100000 feet. For fixed or movable obstacles, the altitude of the highest point should be reported.

3.2.4.2.1 Pressure Altitude

ADS-B link equipment **shall (R3.055)** {from 242AR2.21} support a means for the pilot to indicate that the broadcast of altitude information from pressure altitude sources is invalid. This capability can be used at the request of ATC or when altitude is determined to be invalid by the pilot.

Barometric pressure altitude is the reference for vertical separation within the NAS and ICAO airspace. Barometric pressure altitude is reported referenced to standard temperature and pressure.

Pressure altitude, which is currently reported by aircraft in SSR Mode C and Mode S, will also be transmitted in ADS-B Messages and reported to client applications in SV Reports. The pressure altitude reported **shall (R3.056)** {from 242AR2.22} be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.

3.2.4.2.2 Geometric Altitude

Geometric altitude is defined as the shortest distance from the current aircraft position to the surface of the WGS-84 ellipsoid, known as Height Above Ellipsoid (HAE). It is positive for positions above the WGS-84 ellipsoid surface, and negative for positions below that surface.

3.2.5 Horizontal Velocity

There are two kinds of velocity information:

- "Ground-referenced" or geometric velocity is the velocity of an A/V relative to a coordinate system that is fixed with respect to the earth. Ground-referenced velocity is communicated in the SV Report (§3.5.1.3).
- Air-Referenced Velocity (ARV) is the velocity of an aircraft relative to the air mass through which it is moving. Airspeed, the *magnitude* of the air-referenced velocity vector, is communicated in the ARV report, §3.5.1.6. The ARV report also includes heading (§3.5.1.6.6), which is used in that report as an estimate of the *direction* of the air-referenced velocity vector. Conditions for when the broadcast of ARV data is required are specified in §3.5.1.6.1.

ADS-B geometric velocity information **shall (R3.057)** {from 242AR2.23} be referenced to WGS-84. Transmitting A/Vs that are not fixed or movable obstacles **shall (R3.058)** {from 242AR2.24} provide ground-referenced geometric horizontal velocity.

Note: *In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its horizontal velocity may be ignored.*

3.2.6 Vertical Rate

Transmitting A/Vs that are not fixed or movable obstacles and that are not known to be on the airport surface **shall (R3.059)** {from 242AR2.25} provide vertical rate.

Note 1: *In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its vertical rate may be ignored.*

Vertical Rate **shall (R3.060)** {from 242AR2.26} be designated as climbing or descending and **shall (R3.061)** {from 242AR2.27} be reported up to 32000 feet per minute (fpm). Barometric altitude rate is defined as the current rate of change of barometric altitude. Likewise, geometric altitude rate is the rate of change of geometric altitude. At least one of the two types of vertical rate (barometric and geometric) **shall (R3.062)** {from 242AR2.28} be reported.

If only one of these two types of vertical rate is reported, it **shall (R3.063)** {from 242AR2.29} be obtained from the best available source of vertical rate information.

1. Inertial filtered barometric altitude rate will be the preferred source of altitude rate information.

2. If differentially corrected GNSS (WAAS, LAAS, or other) is available, geometric altitude rate as derived from the GPS source should be transmitted.

3. If differentially corrected GNSS is not available, un-augmented GNSS vertical rate should be used.

4. Pure barometric rate.

Note 2: *Future versions of these MASPS are expected to include requirements on the accuracy and latency of barometric altitude rate.*

Note 3: *Vertical rate is reported in the SV Report (§3.5.1.3.16).*

3.2.7 Heading

Heading indicates the orientation of an A/V, that is, the direction in which the nose of the aircraft is pointing. Heading is described as an angle measured clockwise from true north or magnetic north. The heading reference direction (true north or magnetic north) is conveyed in the Mode Status Report (§3.5.1.4).

Heading occurs not only in the SV Report (§3.5.1.3) for participants on the airport surface, but also in the ARV report (§3.5.1.6) for airborne participants.

3.2.8 Capability Class (CC) Codes

A transmitting ADS-B participant broadcasts Capability Class (CC) codes (§3.5.1.4.9) so as to indicate capabilities that may be of interest to other ADS-B participants. The subfields of the CC codes field are described in the following subparagraphs.

3.2.8.1 TCAS/ACAS Operational

The CC code for "TCAS/ACAS operational" **shall (R3.064)** {from 242AR3.102-A} be set to ONE if the transmitting subsystem receives information from an appropriate interface that indicates that the TCAS/ACAS system is operational. Otherwise, this CC code **shall (R3.065)** {from 242AR3.102-C} be set to ZERO.

Notes:

1. *ADS-B does not consider TCAS/ACAS Operational equal to ONE (1) unless the TCAS/ACAS is in a state which can issue an RA (e.g., RI=3 or 4). RTCA DO-181E (EUROCAE ED-73E) [18] Mode-S Transponders consider that the TCAS System is operational when "MB" bit 16 of Register 10_{16} is set to "ONE" (1). This occurs when the transponder / TCAS/ACAS interface is operational and the transponder is receiving TCAS RI=2, 3 or 4. (Refer to RTCA DO-181E (EUROCAE ED-73E), Appendix B, Table B-3-16.) RI=0 is STANDBY, RI=2 is TA ONLY and RI=3 is TA/RA.*

2. *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.2.8.2 1090 MHz ES Receive Capability

The CC Code for "1090ES IN" **shall (R3.066)** {from 242AR3.103-C} be set to ONE (1) if the transmitting aircraft also has the capability to receive ADS-B 1090ES Messages. Otherwise, this CC code subfield **shall (R3.067)** {from 242AR3.103-D} be set to ZERO (0).

3.2.8.3 ARV Report Capability Flag

The Air Reference Velocity (ARV) Report Capability Flag is a one-bit field that **shall (R3.068)** {from 242AR3.106} be encoded as in Table 3-4.

Table 3-4: ARV Report Capability Flag

ARV Capability Flag	Meaning
0	No capability for sending messages to support Air Referenced Velocity Reports
1	Capability of sending messages to support Air-Referenced Velocity Reports.

3.2.8.4 TS Report Capability Flag

The Target State (TS) Report Capability Flag is a one-bit field that **shall (R3.069)** {from 242AR3.107} be encoded as in Table 3-5.

Table 3-5: TS Report Capability Flag

TS Report Capability Flag	Meaning
0	No capability for sending messages to support Target State Reports.
1	Capability of sending messages to support Target State Reports.

3.2.8.5 TC Report Capability Level

The Trajectory Change (TC) Report Capability Level is a two-bit field that **shall (R3.070)** {from 242AR3.108} be encoded as in Table 3-6.

<u>Table 3-6:</u> TC Report Capability Levels

TC Report Capability Level	Meaning
0	No capability for sending messages to support Trajectory Change Reports
1	Capability of sending messages to support TC+0 report only.
2	Capability of sending information for multiple TC reports.
3	(Reserved for future use.)

3.2.8.6 UAT Receive Capability

The “UAT IN” CC Code **shall (R3.071)** {from 242AR3.109-C} be set to ZERO (0) if the aircraft is NOT fitted with the capability to receive ADS-B UAT Messages. The “UAT IN” CC Code **shall (R3.072)** {from 242AR3.109-D} be set to ONE (1) if the aircraft has the capability to receive ADS-B UAT Messages.

3.2.8.7 Other Capability Codes

Other capability codes are expected to be defined in later versions of these MASPS.

3.2.9 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational modes of transmitting ADS-B participants. Specific operational mode codes are described in the following subparagraphs.

3.2.9.1 TCAS/ACAS Resolution Advisory Active Flag

The CC code for “TCAS/ACAS Resolution Advisory Active” **shall (R3.073)** {from 242AR3.110-A} be set to ONE if the transmitting aircraft has a TCAS II or ACAS computer that is currently issuing a Resolution Advisory (RA). Likewise, this CC code **shall (R3.074)** {from 242AR3.110-B} be set to ONE if the transmitting ADS-B equipment cannot ascertain whether the TCAS II or ACAS computer is currently issuing an RA. This CC code **shall (R3.075)** {from 242AR3.110-C} be ZERO only if it is explicitly known that a TCAS II or ACAS computer is not currently issuing a Resolution Advisory (RA).

<u>Note:</u> *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.2.9.2 IDENT Switch Active Flag

The “IDENT Switch Active” Flag is a one-bit OM code that is activated by an IDENT switch. Upon activation of the IDENT switch, this flag **shall (R3.076)** {from 242AR3.111-B} be set to ONE for a period of 20 ±3 seconds; thereafter, it **shall (R3.077)** {from 242AR3.111-C} be reset to ZERO.

Note: *These MASPS do not specify the means by which the “IDENT Switch Active” flag is set. That is left to lower-level documents, such as the MOPS for a particular ADS-B data link.*

3.2.9.3 Reserved for Receiving ATC Services Flag

The “Reserved for Receiving ATC Services” flag is a one-bit OM code. If implemented into future versions of these MASPS, when set to ONE, this code **shall (R3.078)** {from 242AR3.112} indicate that the transmitting ADS-B participant is receiving ATC services; otherwise this flag should be set to ZERO.

Note: *The means by which the “Reserved for Receiving ATC Services” flag is set is beyond the scope of these MASPS and is not specified in this document.*

3.2.9.4 Other Operational Mode Codes

Other operational mode (OM) codes may be defined in later versions of these MASPS.

3.2.10 Navigation Integrity Category

The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable integrity containment region for the intended use. The Navigation Integrity Category is intimately associated with the Source Integrity Level (SIL) parameter described in §3.2.13. NIC specifies an integrity containment region. The SIL parameter specifies the probability of the reported horizontal position exceeding the containment radius defined by the NIC without alerting, assuming no avionics faults.

Note: *“NIC” and “NAC_P” as used in these MASPS was previously changed in an earlier version of the ADS-B MASPS (RTCA DO-242A) [27], which replaced the earlier term, “NUC_P”, used in the first edition of the ADS-B MASPS (RTCA DO-242) [26].*

The Navigation Integrity Category (NIC) is reported in the State Vector (SV) Report (§3.5.1.3.18).

Table 3-7 defines the navigation integrity categories that transmitting ADS-B participants **shall (R3.079)** {from 242AR2.30} use to describe the integrity containment radius, R_C, associated with the horizontal position information in ADS-B Messages from those participants.

<u>Table 3-7:</u> Navigation Integrity Categories (NIC).

NIC (Notes 1, 2)	**Horizontal Containment Bounds**	**Notes**
0	R_C Unknown	
1	R_C < 37.04 km (20 NM)	6
2	R_C < 14.816 km (8 NM)	3, 6
3	R_C < 7.408 km (4 NM)	6
4	R_C < 3.704 km (2 NM)	6
5	R_C < 1852 m (1 NM)	6
6	R_C < 1111.2 m (0.6 NM)	5, 6
6	R_C < 555.6 m (0.3 NM)	5, 6
7	R_C < 370.4 m (0.2 NM)	6
8	R_C < 185.2 m (0.1 NM)	6
9	R_C < 75 m	4
10	R_C < 25 m	4
11	R_C < 7.5 m	4

<u>Notes for Table 3-7:</u>

1. *NIC is reported by an aircraft because there will not be a uniform level of navigation equipage among all users. Although GNSS is intended to be the primary source of navigation data used to report ADS-B horizontal position, it is anticipated that during initial uses of ADS-B or during temporary GNSS outages an alternate source of navigation data may be used by the transmitting A/V for ADS-B position information.*

2. *"NIC" in this column corresponds to "NUC_P" of Table 2-1(a) in the first version of these MASPS, RTCA DO-242 [26], dated February 19, 1998.*

3. *The containment radius for NIC=2 has been changed (from the corresponding radius for NUC_P =2 in the first edition of these MASPS) so as to correspond to the RNP-4 RNAV limit of RTCA DO-236A [25], rather than the RNP-5 limit of the earlier RTCA DO-236. This is because RNP-5 is not a recognized ICAO standard RNP value.*

4. *HIL/HPL may be used to represent R_C for GNSS sensors.*

5. *R_C < 0.3 NM was added in this version of these MASPS and assigned NIC value of 6. It is left to the ADS-B data link to provide a means to distinguish between R_C < 0.3 NM and R_C < 0.6 NM.*

6. *RNP containment integrity refers to total system error containment including sources other than sensor error, whereas horizontal containment for NIC only refers to sensor position error containment.*

7. *In previous versions of these MASPS, there were expressed dependencies on the Vertical Protection Limit in the ADS-B accuracy and integrity parameters. With the publication of ADS-B MOPS for Version Number of 2, these dependencies were removed from the NIC, NAC_P, NAC_V and SIL parameters, and a new Geometric Vertical Accuracy (GVA) parameter was introduced.*

It is recommended that the coded representations of NIC should be such that:

a. Equipment that conforms to the current edition of these MASPS ("version 2" equipment) or to the previous, RTCA DO-242A [27], edition ("version 1" equipment) will recognize the equivalent NUC_P codes from the first edition of these MASPS (RTCA DO-242 [26], version "0" equipment), and

b. Equipment that conforms to the initial, RTCA DO-242 [26], edition of these MASPS ("version 0" equipment) will treat the coded representations of NIC coming from version 1 or 2 equipment as if they were the corresponding "NUC_P" values from the initial, RTCA DO-242 [26], version of these MASPS.

3.2.11 Navigation Accuracy Category for Position (NAC_P)

The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported geometric position has an acceptable level of accuracy for the intended use.

Table 3-8 defines the navigation accuracy categories that **shall (R3.080)** {from 242AR2.31} be used to describe the accuracy of positional information in ADS-B Messages from transmitting ADS-B participants.

<u>Notes:</u>

1. *"NIC" and "NAC_P" as used in these MASPS replace the earlier term, "NUC_P", used in the initial, RTCA DO-242 [26], edition of these MASPS .*

2. *It is likely that surface movement and runway incursion applications will require high NAC_P values. To obtain those high values, it may be necessary to correct the reported position to that of the ADS-B Position Reference Point (§3.2.4.1) if the antenna of the navigation sensor is not located in very close proximity to the ADS-B Position Reference Point.*

3. *The Estimated Position Uncertainty (EPU) used in Table 3-8 is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

4. *The EPU limit for NAC_P = 2 has been changed (from the corresponding limit for NUC_P = 2 in the first edition of these MASPS) so as to correspond to the RNP-4 RNAV limit of RTCA DO-236A [25], rather than the RNP-5 limit of the earlier RTCA DO-236. This is because RNP-5 is not an ICAO standard RNP value.*

Table 3-8: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal Accuracy Bounds (EPU)	Notes
0	EPU ≥ 18.52 km (10 NM)	
1	EPU < 18.52 km (10 NM)	1
2	EPU < 7.408 km (4 NM)	1
3	EPU < 3.704 km (2 NM)	1
4	EPU < 1852 m (1NM)	1
5	EPU < 926 m (0.5 NM)	1
6	EPU < 555.6 m (0.3 NM)	1
7	EPU < 185.2 m (0.1 NM)	1
8	EPU < 92.6 m (0.05 NM)	1
9	EPU < 30 m	2
10	EPU < 10 m	2
11	EPU < 3 m	2

Notes for Table 3-8:

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2. *A non-excluded satellite failure requires that the NAC_P and NAC_V parameters be set to ZERO along with R_C being set to Unknown to indicate that the position accuracy and integrity have been determined to be invalid. Factors such as surface multi-path, which has been observed to cause intermittent setting of Label 130 bit 11, should be taken into account by the ADS-B application and ATC.*

3. *In previous versions of these MASPS, there were expressed dependencies on the Vertical Protection Limit in the ADS-B accuracy and integrity parameters. With the publication of ADS-B MOPS for Version Number of 2, these dependencies were removed from the NIC, NAC_P, NAC_V and SIL parameters, and a new Geometric Vertical Accuracy (GVA) parameter was introduced.*

3.2.12 Navigation Accuracy Category for Velocity (NAC_V)

The velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data **shall (R3.081)** {from 242AR2.33} be as indicated in Table 3-9.

Notes:

1. *NAC_V is another name for the parameter that was called NUC_R in the initial (DO-242) version of these MASPS.*

2. *Navigation sources, such as GNSS and inertial navigation systems, provide a direct measure of velocity which can be significantly better than that which could be obtained by position differences.*

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3. Refer to RTCA DO-260B [37], Appendix J (RTCA DO-282B [42], Appendix Q) for guidance material on determination of NAC_V. The referenced Appendices describe the manner in which GNSS position sources, which do not output velocity accuracy, can be characterized so that a velocity accuracy value associated with the position source can be input into ADS-B equipment as part of the installation process.

<u>Table 3-9:</u> Navigation Accuracy Categories for Velocity (NAC_V).

NAC_V	Horizontal Velocity Error (95%)
0	Unknown or ≥ 10 m/s
1	< 10 m/s
2	< 3 m/s
3	< 1 m/s
4	< 0.3 m/s

<u>Notes for Table 3-9:</u>

1. When an inertial navigation system is used as the source of velocity information, error in velocity with respect to the earth (or to the WGS-84 ellipsoid used to represent the earth) is reflected in the NAC_V value.

2. When any component of velocity is flagged as not available the value of NAC_V will apply to the other components that are supplied.

3. A non-excluded satellite failure requires that the R_C be set to Unknown along with the NAC_V and NAC_P parameters being set to ZERO.

4. In previous versions of these MASPS, there were expressed dependencies on the Vertical Protection Limit in the ADS-B accuracy and integrity parameters. With the publication of ADS-B MOPS for Version Number of 2, these dependencies were removed from the NIC, NAC_P, NAC_V and SIL parameters, and a new Geometric Vertical Accuracy (GVA) parameter was introduced.

3.2.13 Source Integrity Level (SIL)

The Source Integrity Level (SIL) defines the probability of the reported horizontal position exceeding the containment radius defined by the NIC (§3.2.10), without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-in-Space, if a Signal-in-Space is used by the position source. The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the System Design Assurance (SDA) (§3.2.32) parameter. The Source Integrity Level **shall (R3.082)** {from 242AR2.34} be encoded as indicated in Table 3-10. The SIL probability **shall (R3.083)** {new reqmt} be defined as either “per sample” or “per flight hour.”

Notes:

1. *It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GNSS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV Report.*

2. *In previous versions of these MASPS, there were expressed dependencies on the Vertical Protection Limit in the ADS-B accuracy and integrity parameters. With the publication of ADS-B MOPS for Version Number of 2, these dependencies were removed from the NIC, NAC_P, NAC_V and SIL parameters, and a new Geometric Vertical Accuracy (GVA) parameter was introduced.*

Table 3-10: Source Integrity Level (SIL) Encoding.

SIL	Probability of Exceeding the NIC Containment Radius
0	Unknown or > 1 x 10^{-3} per flight hour or per sample
1	1×10^{-3} per flight hour or per sample
2	1×10^{-5} per flight hour or per sample
3	1×10^{-7} per flight hour or per sample

3.2.14 Barometric Altitude Integrity Code (NIC_{BARO})

The Barometric Altitude Integrity Code, NIC_{BARO}, is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude.

Note: *NIC_{BARO}, the barometric altitude integrity code, is reported in the Mode Status report (§3.5.1.4).*

3.2.15 Emergency/Priority Status

The ADS-B system **shall (R3.084)** {from 242AR2.36} be capable of supporting broadcast of emergency and priority status. Emergency/priority status is reported in the MS Report (§3.5.1.4) and the emergency states are defined in Table 3-11.

Table 3-11: Emergency State Encoding

Value	Meaning
0	No Emergency
1	General Emergency
2	Lifeguard / Medical
3	Minimum Fuel
4	No Communications
5	Unlawful Interference
6	Downed Aircraft
7	Reserved

3.2.16 Geometric Vertical Accuracy (GVA)

The Geometric Vertical Accuracy subfield is a 2-bit field as specified in Table 3-12. The GVA field **shall (R3.085)** {new reqmt} be set by using the Vertical Figure of Merit (VFOM) (95%) from the GNSS position source used to report the geometric altitude.

Table 3-12: Geometric Vertical Accuracy (GVA) Parameter

GVA Encoding (decimal)	Meaning (meters)
0	Unknown or > 150 meters
1	≤ 150 meters
2	≤ 45 meters
3	Reserved

Notes:

1. *For the purposes of these MASPS, values for 0, 1 and 2 are encoded. Decoding values for 3 should be treated as < 45 meters until future versions of these MASPS redefine the value.*

2. *In previous versions of these MASPS, there were expressed dependencies on the Vertical Protection Limit in the ADS-B accuracy and integrity parameters. With the publication of ADS-B MOPS for Version Number of 2, these dependencies were removed from the NIC, NAC_P, NAC_V and SIL parameters, and a new Geometric Vertical Accuracy (GVA) parameter was introduced.*

3.2.17 TCAS/ACAS Resolution Advisory (RA) Data Block

For those aircraft equipped with TCAS/ACAS, in addition to the TCAS/ACAS Resolution Advisory Active broadcast flag, the RA Message Block is also required to be broadcast during an active RA and following termination so that ADS-B receiving systems can sense the termination of the RA. The message subfields are the data elements that are specified in RTCA DO-185B, §2.2.3.9.3.2.3.1.1.

3.2.18 ADS-B Version Number

The ADS-B Version Number is a 3-bit field that specifies the ADS-B version of the ADS-B Transmitting Subsystem. The ADS-B Version Number **shall (R3.086)** {from 242AR3.92} be defined as specified in Table 3-13 below.

<u>Table 3-13:</u> ADS-B Version Number

ADS-B Version	Relevant Standards Document
0	RTCA DO-242
1	RTCA DO-242A
2	RTCA DO-260B / EUROCAE ED-102A & RTCA DO-282B
3-7	Reserved for future growth.

3.2.19 Selected Altitude Type

a. The "Selected Altitude Type" subfield is a 1-bit field that is used to indicate the source of Selected Altitude data. Encoding of the "Selected Altitude Type" **shall (R3.087)** {from 242AR3.132-A} be in accordance with Table 3-14.

b. Whenever there is no valid MCP / FCU or FMS Selected Altitude data available, then the "Selected Altitude Type" subfield **shall (R3.088)** {from 242AR3.132-B} be set to ZERO (0).

<u>Note:</u> *Users of this data are cautioned that the selected altitude value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during certain VNAV or Approach modes), and does not necessarily correspond to the target altitude (the next altitude level at which the aircraft will level off).*

In addition, on many airplanes, the ADS-B Transmitting Subsystem does not receive selected altitude data from the FMS and will only transmit Selected Altitude data received from a Mode Control Panel / Flight Control Unit (MCP / FCU).

<u>Table 3-14:</u> Selected Altitude Type Field Values

Coding	Meaning
0	Data being used to encode the Selected Altitude data field is derived from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment.
1	Data being used to encode the Selected Altitude data field is derived from the Flight Management System (FMS).

3.2.20 MCP/FCU or FMS Selected Altitude Field

a. The "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield is an 11-bit field that **shall (R3.089)** {from 242AR3.133-A} contain either the MCP / FCU Selected Altitude or the FMS Selected Altitude data in accordance with the following subparagraphs.

b. Whenever valid Selected Altitude data is available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, such data **shall (R3.090)** {from 242AR3.133-B} be used to encode the Selected Altitude data field in accordance with Table 3-15. Use of MCP / FCU Selected Altitude **shall (R3.091)** {from 242AR3.133-C} then be declared in the "Selected Altitude Type" subfield as specified in Table 3-14.

c. Whenever valid Selected Altitude data is NOT available from the Mode Control Panel / Flight Control Unit (MCP / FCU) or equivalent equipment, but valid Selected Altitude data is available from the Flight Management System (FMS), then the FMS Selected Altitude data **shall (R3.092)** {from 242AR3.133-D} be used to encode the Selected Altitude data field in accordance with Table 3-15 provided in paragraph "d." Use of FMS Selected Altitude **shall (R3.093)** {from 242AR3.133-E} then be declared in the "Selected Altitude Type" subfield as specified in Table 3-14.

d. Encoding of the Selected Altitude data field **shall (R3.094)** {from 242AR3.133-F} be in accordance with Table 3-15. Encoding of the data **shall (R3.095)** {from 242AR3.133-G} be rounded so as to preserve accuracy of the source data within ±½ LSB.

e. Whenever there is NO valid MCP / FCU or FMS Selected Altitude data available, then the "MCP / FCU Selected Altitude or FMS Selected Altitude" subfield **shall (R3.096)** {from 242AR3.133-H} be set to ZERO (0) as indicated in Table 3-15.

Note: *Users of this data are cautioned that the selected altitude value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during certain VNAV or Approach modes), and does not necessarily correspond to the target altitude (the next altitude level at which the aircraft will level off).*

In addition, on many airplanes, the ADS-B Transmitting Subsystem does not receive selected altitude data from the FMS and will only transmit Selected Altitude data received from a Mode Control Panel / Flight Control Unit (MCP / FCU).

Table 3-15: "MCP/FCU Selected Altitude or FMS Selected Altitude" Field Values

Coding		Meaning
(Binary)	(Decimal)	
000 0000 0000	0	**NO Data *or* INVALID Data**
000 0000 0001	1	0 feet
000 0000 0010	2	32 feet
000 0000 0011	3	64 feet
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
*** **** ****	***	*** **** ****
111 1111 1110	2046	65440 feet
111 1111 1111	2047	65472 feet

3.2.21 Barometric Pressure Setting (Minus 800 millibars) Field

a. The "Barometric Pressure Setting (Minus 800 millibars)" subfield is a 9-bit field that **shall (R3.097)** {from 242AR3.136-A} contain Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source.

b. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting **shall (R3.098)** {from 242AR3.136-B} be encoded in accordance with Table 3-16.

c. Encoding of Barometric Pressure Setting data **shall (R3.099)** {from 242AR3.136-C} be rounded so as to preserve a reporting accuracy within ±½ LSB.

d. Whenever there is NO valid Barometric Pressure Setting data available, then the "Barometric Pressure Setting (Minus 800 millibars) subfield **shall (R3.100)** {from 242AR3.136-D} be set to ZERO (0) as indicated in Table 3-16.

e. Whenever the Barometric Pressure Setting data is greater than 1208.4 or less than 800 millibars, then the "Barometric Pressure Setting (Minus 800 millibars}" subfield **shall (R3.101)** {from 242AR3.136-E} be set to ZERO (0).

Note: *This Barometric Pressure Setting data can be used to represent QFE or QNH/QNE, depending on local procedures. It represents the current value being used to fly the aircraft.*

Table 3-16: Barometric Pressure Setting (Minus 800 millibars) Field Values

Value (Binary)	Value (Decimal)	Meaning
0 0000 0000	0	**NO Data *or* INVALID Data**
0 0000 0001	1	0 millibars
0 0000 0010	2	0.8 millibars
0 0000 0011	3	1.6 millibars
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
* **** ****	***	*** **** ****
1 1111 1110	510	407.2 millibars
1 1111 1111	511	408.0 millibars

3.2.22 Selected Heading Status Field

The "Selected Heading Status" is a 1-bit field that **shall (R3.102)** {from 242AR3.137-A} be used to indicate the status of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3-17.

Table 3-17: Selected Heading Status Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is either **NOT** Available or is **INVALID**. See Table 3-19.
1	Data being used to encode the Selected Heading data is Available and is **VALID**. See Table 3-19.

3.2.23 Selected Heading Sign Field

The "Selected Heading Sign" is a 1-bit field that **shall (R3.103)** {from 242AR3.138-A} be used to indicate the arithmetic sign of Selected Heading data that is being used to encode the Selected Heading data in accordance with Table 3-18.

Table 3-18: Selected Heading Sign Field Values

Value	Meaning
0	Data being used to encode the Selected Heading data is Positive in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is positive or Zero for all values that are less than 180 degrees). See Table 3-19.
1	Data being used to encode the Delected Heading data is Negative in an angular system having a range between +180 and –180 degrees. (For an Angular Weighted Binary system which ranges from 0.0 to 360 degrees, the sign bit is ONE for all values that are greater than 180 degrees). See Table 3-19.

3.2.24 Selected Heading Field

a. The “Selected Heading” is an 8-bit field that **shall (R3.104)** {from 242AR3.139-A} contain Selected Heading data encoded in accordance with Table 3-19.

b. Encoding of Selected Heading data **shall (R3.105)** {from 242AR3.139-B} be rounded so as to preserve accuracy of the source data within ±½ LSB.

c. Whenever there is NO valid Selected Heading data available, then the Selected Heading Status, Sign, and Data subfields **shall (R3.106)** {from 242AR3.139-C} be set to ZERO (0) as indicated in Table 3-19.

Note: *On many airplanes, the ADS-B Transmitting Subsystem receives Selected Heading from a Mode Control Panel / Flight Control Unit (MCP / FCU). Users of this data are cautioned that the Selected Heading value transmitted by the ADS-B Transmitting Subsystem does not necessarily reflect the true intention of the airplane during certain flight modes (e.g., during LNAV mode).*

Table 3-19: Selected Heading Status, Sign and Data Field Values

Values for Selected Heading:			Meaning
Status	**Sign**	**Data**	
0	0	0000 0000	**NO Data *or* INVALID Data**
1	0	0000 0000	0.0 degrees
1	0	0000 0001	0.703125 degrees
1	0	0000 0010	1.406250 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	0	1111 1111	179.296875 degrees
1	1	0000 0000	180.0 or -180.0 degrees
1	1	0000 0001	180.703125 or -179.296875 degrees
1	1	0000 0010	181.406250 or -178.593750 degrees
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
*	*	**** ****	**** **** ****
1	1	1000 0000	270.000 or -90.0000 degrees
1	1	1000 0001	270.703125 or -89.296875 degrees
1	1	1000 0010	271.406250 or -88.593750 degrees
1	1	1111 1110	358.593750 or -1.4062500 degrees
1	1	1111 1111	359.296875 or -0.7031250 degrees

3.2.25 Status of MCP/FCU Mode Bits

The “Status of MCP / FCU Mode Bits” is a 1-bit field that **shall (R3.107)** {from 242AR3.140-A} be used to indicate whether the mode indicator bits are actively being populated (e.g., set) in accordance with Table 3-20.

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If information is provided to the ADS-B Transmitting Subsystem to set the Mode Indicator bits to either “0” or “1,” then the “Status of MCP/FCU Mode Bits” **shall (R3.108)** {from 242AR3.140-B} be set to ONE (1). Otherwise, the “Status of MCP/FCU Mode Bits” **shall (R3.109)** {from 242AR3.140-C} be set to ZERO (0).

Table 3-20: Status of MCP/FCU Mode Bits Field Values

Values	Meaning
0	No Mode Information is being provided in the Mode Indicator bits
1	Mode Information is deliberately being provided in the Mode Indicator bits

3.2.26 Mode Indicator: Autopilot Engaged Field

The “Mode Indicator: Autopilot Engaged” subfield is a 1-bit field that **shall (R3.110)** {from 242AR3.142-A} be used to indicate whether the autopilot system is engaged or not.

a. The ADS-B Transmitting Subsystem **shall (R3.111)** {from 242AR3.142-B} accept information from an appropriate interface that indicates whether or not the Autopilot is engaged.

b. The ADS-B Transmitting Subsystem **shall (R3.112)** {from 242AR3.142-C} set the Mode Indicator: Autopilot Engaged field in accordance with Table 3-21.

Table 3-21: Mode Indicator: Autopilot Engaged Field Values

Values	Meaning
0	Autopilot is NOT Engaged or Unknown (e.g., not actively coupled and flying the aircraft)
1	Autopilot is Engaged (e.g., actively coupled and flying the aircraft)

3.2.27 Mode Indicator: VNAV Mode Engaged Field

The “Mode Indicator: VNAV Mode Engaged” is a 1-bit field that **shall (R3.113)** {from 242AR3.146-A} be used to indicate whether the Vertical Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall (R3.114)** {from 242AR3.146-B} accept information from an appropriate interface that indicates whether or not the Vertical Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall (R3.115)** {from 242AR3.146-C} set the Mode Indicator: VNAV Mode Engaged field in accordance with Table 3-22.

Table 3-22: “Mode Indicator: VNAV Engaged” Field Values

Values	Meaning
0	VNAV Mode is NOT Active or Unknown
1	VNAV Mode is Active

3.2.28 Mode Indicator: Altitude Hold Mode Field

The "Mode Indicator: Altitude Hold Mode" is a 1-bit field that **shall (R3.116)** {from 242AR3.147-A} be used to indicate whether the Altitude Hold Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall (R3.117)** {from 242AR3.147-B} accept information from an appropriate interface that indicates whether or not the Altitude Hold Mode is active.

b. The ADS-B Transmitting Subsystem **shall (R3.118)** {from 242AR3.147-C} set the Mode Indicator: Altitude Hold Mode field in accordance with Table 3-23.

Table 3-23: "Mode Indicator: Altitude Hold Mode" Field Values

Values	Meaning
0	Altitude Hold Mode is NOT Active or Unknown
1	Altitude Hold Mode is Active

3.2.29 Mode Indicator: Approach Mode Field

The "Mode Indicator: Approach Mode" is a 1-bit field that **shall (R3.119)** {from 242AR3.148-A} be used to indicate whether the Approach Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall (R3.120)** {from 242AR3.148-B} accept information from an appropriate interface that indicates whether or not the Approach Mode is active.

b. The ADS-B Transmitting Subsystem **shall (R3.121)** {from 242AR3.148-C} set the Mode Indicator: Approach Mode field in accordance with Table 3-24.

Table 3-24: "Mode Indicator: Approach Mode" Field Values

Values	Meaning
0	Approach Mode is NOT Active or Unknown
1	Approach Mode is Active

3.2.30 Mode Indicator: LNAV Mode Engaged Field

The "Mode Indicator: LNAV Mode Engaged" is a 1-bit field that **shall (R3.122)** {from 242AR3.149-A} be used to indicate whether the Lateral Navigation Mode is active or not.

a. The ADS-B Transmitting Subsystem **shall (R3.123)** {from 242AR3.149-B} accept information from an appropriate interface that indicates whether or not the Lateral Navigation Mode is active.

b. The ADS-B Transmitting Subsystem **shall (R3.124)** {from 242AR3.149-C} set the Mode Indicator: LNAV Mode Engaged field in accordance with Table 3-25.

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Table 3-25: "Mode Indicator: LNAV Mode Engaged" Field Values

Values	Meaning
0	LNAV Mode is NOT Active
1	LNAV Mode is Active

3.2.31 Single Antenna Flag (SAF)

The "Single Antenna Flag" (SAF) is a 1-bit field that **shall (R3.125)** {from 242AR3.112-A} be used to indicate that the ADS-B Transmitting Subsystem is operating with a single antenna. The following conventions **shall (R3.126)** {from 242AR3.112-B} apply both to Transponder-Based and Stand Alone ADS-B Transmitting Subsystems:

a. Non-Diversity, i.e., those transmitting functions that use only one antenna, **shall (R3.127)** {from 242AR3.112-C} set the Single Antenna subfield to "ONE" at all times.

b. Diversity, i.e., those transmitting functions designed to use two antennas, **shall (R3.128)** {from 242AR3.112-D} set the Single Antenna subfield to "ZERO" at all times that both antenna channels are functional.

At any time that the diversity configuration cannot guarantee that both antenna channels are functional, then the Single Antenna Flag **shall (R3.129)** {from 242AR3.112-E} be set to "ONE."

Note: *Certain applications may require confirmation that each participant has functioning antenna diversity for providing adequate surveillance coverage.*

3.2.32 System Design Assurance (SDA)

The position transmission chain includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data and position quality metrics that will be transmitted.

The "System Design Assurance" (SDA) field is a 2-bit field that **shall (R3.130)** {from 242AR3.112-F} define the failure condition that the position transmission chain is designed to support as defined in Table 3-26.

The supported failure condition will indicate the probability of a position transmission chain fault causing false or misleading position information to be transmitted. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1A [8], AC 23-1309-1D [7], and AC 29-2C [9]. All relevant systems attributes should be considered including software and complex hardware in accordance with RTCA DO-178B [17] (EUROCAE ED-12B) or RTCA DO-254 [32] (EUROCAE ED-80).

Table 3-26: SDA OM Subfield in Aircraft Operational Status Messages

SDA Value		Supported Failure Condition Note 2	Probability of Undetected Fault causing transmission of False or Misleading Information Note 3, 4	Software & Hardware Design Assurance Level Note 1, 3
(decimal)	(binary)			
0	00	Unknown/ No safety effect	> 1×10^{-3} per flight hour or Unknown	N/A
1	01	Minor	≤ 1×10^{-3} per flight hour	D
2	10	Major	≤ 1×10^{-5} per flight hour	C
3	11	Hazardous	≤ 1×10^{-7} per flight hour	B

Notes:

1. *Software Design Assurance per RTCA DO-178B [17] (EUROCAE ED-12B). Airborne Electronic Hardware Design Assurance per RTCA DO-254 [32] (EUROCAE ED-80).*
2. *Supported Failure Classification defined in AC-23.1309-1D [7], AC-25.1309-1A [8], and AC 29-2C [9].*
3. *Because the broadcast position can be used by any other ADS-B equipped aircraft or by ATC, the provisions in AC 23-1309-1D [7] that allow reduction in failure probabilities and design assurance level for aircraft under 6000 pounds do not apply.*
4. *Includes probability of transmitting false or misleading latitude, longitude, or associated accuracy and integrity metrics.*

3.2.33 GPS Antenna Offset

The "GPS Antenna Offset" field is an 8-bit field in the OM Code Subfield of surface format Aircraft Operational Status Messages that **shall (R3.131)** {from 242AR3.112-G} define the position of the GPS antenna in accordance with the following.

a. Lateral Axis GPS Antenna Offset:

The Lateral Axis GPS Antenna Offset **shall (R3.132)** {from 242AR3.112-H} be used to encode the lateral distance of the GPS Antenna from the longitudinal axis (Roll) of the aircraft. Encoding **shall (R3.133)** {from 242AR3.112-I} be established in accordance with Table 3-27.

Table 3-27: Lateral Axis GPS Antenna Offset Values

			Upper Bound of the GPS Antenna Offset Along Lateral (Pitch) Axis Left or Right of Longitudinal (Roll) Axis	
0 = left 1 = right	**Values**			
	Bit 1	**Bit 0**	**Direction**	**(meters)**
0	0	0	**LEFT**	**NO DATA**
	0	1		2
	1	0		4
	1	1		6
1	0	0	**RIGHT**	0
	0	1		2
	1	0		4
	1	1		6

Notes:

1. *Left means toward the left wing tip moving from the longitudinal center line of the aircraft.*
2. *Right means toward the right wing tip moving from the longitudinal center line of the aircraft.*
3. *Maximum distance left or right of aircraft longitudinal (roll) axis is 6 meters or 19.685 feet. If the distance is greater than 6 meters, then the encoding should be set to 6 meters.*
4. *The "No Data" case is indicated by encoding of "000" as above, while the "ZERO" offset case is represented by encoding of "100" as above.*
5. *The accuracy requirement is assumed to be better than 2 meters, consistent with the data resolution.*

b. Longitudinal Axis GPS Antenna Offset:

The Longitudinal Axis GPS Antenna Offset **shall (R3.134)** {from 242AR3.112-J} be used to encode the longitudinal distance of the GPS Antenna from the NOSE of the aircraft. Encoding **shall (R3.135)** {from 242AR3.112-K} be established in accordance with Table 3-28. If the GPS Antenna Offset is compensated by the Sensor to be the position of the ADS-B participant's ADS-B Position Reference Point (see §3.2.4.1), then the encoding is set to binary "00001" as indicated in Table 3-28.

Table 3-28: Longitudinal Axis GPS Antenna Offset Encoding

Longitudinal Axis GPS Antenna Offset Encoding					
Values					Upper Bound of the GPS Antenna Offset Along Longitudinal (Roll) Axis Aft From Aircraft Nose
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**(meters)**
0	0	0	0	0	**NO DATA**
0	0	0	0	1	Position Offset Applied by Sensor
0	0	0	1	0	2
0	0	0	1	1	4
0	0	1	0	0	6
*	*	*	*	*	***
*	*	*	*	*	***
*	*	*	*	*	***
1	1	1	1	1	60

Notes:

1. *Maximum distance aft from aircraft nose is 60 meters or 196.85 feet. If the distance is greater than 60 meters, then the encoding should be set to 60 meters.*
2. *The accuracy requirement is assumed to be better than 2 meters, consistent with the minimum data resolution of the 2 meter encoding steps.*

3.3 System Application Requirements

3.3.1 Latency

In general, latency is synonymous with data age. As used in this document it is the difference between the time attributed to source data and the time that data are presented at a particular interface. {This definition was adapted from RTCA DO-289 §2.4.5.3.3.4} Some data latency can be compensated with extrapolation techniques; however, there will always be a small amount of latency compensation error that needs to be minimized. This section includes the requirements for the end-to-end latency, referred to as total latency, for ADS-B, ADS-R and TIS-B; the latency allocations to some key subsystems; and the allowable latency compensation error for ADS-B.

3.3.1.1 Definitions Key to Understanding Latency

The following are key definitions related to the understanding of latency. These and other definitions are provided in Appendix A.

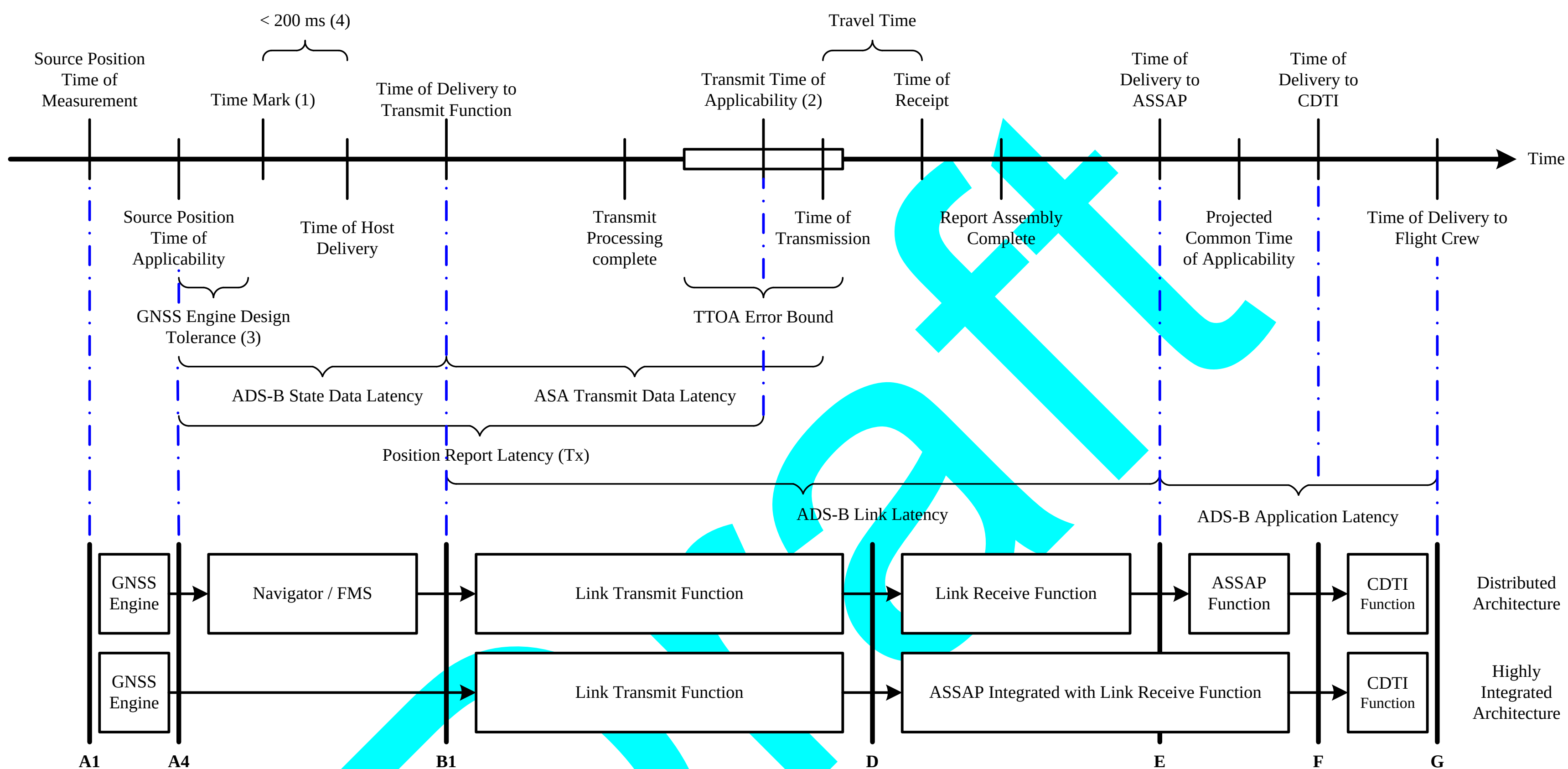
Total Latency: is the total time between the availability of information at a lower interface 'X' to the time of completion of information transfer at an upper interface 'Y'. Total Latency is the sum of Compensated Latency and Latency Compensation Error and is expressed as a single upper value. The related position error is a function of Total Latency and velocity uncertainty.

Compensated Latency: is that part of Total Latency that is compensated for to a new time of applicability, valid at an interface ‘Y’, through data extrapolation aiming at reducing the effects of latency. Compensated Latency may change for each new received/processed track. The related position error is the product of Compensated Latency and the accuracy error of the A/V velocity used for the extrapolation.

Latency Compensation Error (formerly referred to as “Uncompensated Latency”): is that part of Total Latency that is not compensated and/or under/overcompensated for. The value is usually positive but overcompensation might produce negative values as well. The Latency Compensation Error may change for each new received/processed track. The related position error is the product of Latency Compensation Error and true A/V velocity.

Time of Applicability (TOA): at an interface ‘Y’, is the TOA as valid at a lower interface ‘X’ plus the amount of Compensated Latency applied to and valid at an upper interface ‘Y’. Therefore, the Time of Applicability uncertainty is the (sum of) Latency Compensation Errors up to interface ‘Y’. Regarding the notion of a “common” TOA, it is noted that the time of applicability uncertainty will generally vary between tracks.

The ground segment interfaces used to define latency are shown in Figure 1-1 and the airborne interfaces used to define latency measurements shown in Figure 3-11.

3672 

3673 **<u>Figure 3-11:</u> End to End ASA System Latency Diagram**

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Notes:

1. *The Time Mark is an implementation detail of an ARINC 743A compliant GNSS. Other position sensors do not typically output a Time Mark.*
2. *Transmit Time of Applicability (TTOA) may occur before, after, or coincide with Time of Transmission (TOT) depending on the ADS-B link implementation.*
3. *GNSS Engine Design Tolerance is dependent on the implementation of the GNSS engine, but typically is on the order of microseconds.*
4. *RTCA DO-229D requires that the digital solution associated with the Time Mark be delivered in 200 ms.*
5. *The bold lines indicate defined interfaces and match Figure 2-7 in RTCA DO-289 [44]. The exception is interface A4 which doesn't appear in RTCA DO-289 [44] and was added to clarify the latency allocation to the transmit subsystem.*

3.3.1.2 System Interface Definitions

In the following, the term "system interface" expresses timing reference points. With respect to timing requirements, each interface is associated with the time the last bit of a complete data (or signal) set has been transferred over that interface.

Figure 3-11 provides for a detailed end-to-end latency diagram, showing the latency components of both ADS-B Transmit aircraft and ASA aircraft.

The following Figure 3-12 provides for a simple indication of the ASA System latency interfaces with respect to both Ownship and traffic position information.

Figure 3-12: ASA System Latency Diagram

3.3.1.2.1 Interface A1

Interface A1 is defined as the input to the position sensor of an ASA Transmit Participant. The time associated with this physical interface is called the Time of Measurement.

The term Time of Measurement has a very specific meaning in the GNSS literature. It is the time that the Satellite Measurements are sampled with the GNSS RF hardware. Depending on the regulatory document and the equipment class that the GNSS is certified to, the time between the Time of Measurement (A1) and the Time of Applicability (A4) can be 300 ms to 1 second. To meet the Latency allocations in these MASPS, the maximum Total Latency between A1 and A4 may not exceed 500 ms.

3.3.1.2.2 Interface A2

Interface A2 is defined as the input to the position sensor of a TIS-B Participant or the reception of position data of an ADS-R Participant. The time associated with this physical interface is called the Time of Measurement or Time of Reception respectively. This interface is not depicted in Figure 3-11, refer to Figure 1-1.

3.3.1.2.3 Interface A3

Interface A3 is identical to A1 but is defined as applicable to the ownship position source. This interface is not depicted in Figure 3-11, refer to Figure 1-1.

3.3.1.2.4 Interface A4

Interface A4 is introduced in this appendix and defined as the output of the position sensor of an ASA Transmit Participant. The time associated with this physical interface is called the Time of Applicability.

The term Time of Applicability has a very specific meaning in the GNSS literature. It is the time that the digital solution transmitted from the sensor is applicable. This Time of Applicability coincides with the leading edge of a pulse known as the Time Mark. A GNSS sensor provides this pulse on a dedicated set of pins; usually as a differential pair to provide better noise immunity.

The reported digital solution quality metrics (accuracy, integrity) are also valid at the Time of Applicability. Latency present in the system after Interface A4 is NOT accounted for in the quality metrics provided by the GNSS including the Latency inherent in delivering the data to Host/Link Equipment. The latency between A4 and B1 is to be included when establishing the ADS-B State Data Latency.

3.3.1.2.5 Interface A5

This interface is identical to A4 but is defined as applicable to the ownship position source. As between A4 and B1, the latency between A5 and B3 resulting from the various system elements that can be included between both interfaces, has to be included when establishing the ownship State Data Latency. This interface is not depicted in Figure 3-11.

3.3.1.2.6 Interface B1

Interface B1 is defined as the input to the ADS-B Transmit Subsystem. The requirements of this function are controlled by RTCA DO-260() / EUROCAE ED-102() [37], RTCA DO-282() [42] and EUROCAE ED-108() [4]. In a distributed architecture, there could be various system elements between A4 and B1. For instance, a modern integrated cockpit with a high speed data bus may require a block of circuitry on either side of it to transfer PVT data on and off of the bus.

For GNSS systems, the maximum Total Latency between A4 and B1 may not exceed 400 ms. This latency is usually not compensated for and, hence, becomes part of the Latency Compensation Error budget.

3.3.1.2.7 Interface B2

Interface B2 is defined as the input to the TIS-B & ADS-R Surveillance Processing and Distribution system. This interface is not depicted in Figure 3-11, refer to Figure 1-1.

3.3.1.2.8 Interface B3

Interface B3 is defined as the input to the ASSAP function on ownship. This interface is not depicted in Figure 3-11, refer to Figure 1-1.

3.3.1.2.9 Interface D

Interface D is defined as the Time of Transmission (i.e., the RF message leaving the transmit antenna). Depending on which transmit case is implemented in the link equipment, the Transmit Time of Applicability may coincide with the Time of Transmission or be within some specified time tolerance between these.

For the purposes of latency allocation, Travel Time is not significant. Therefore, Interface D also defines the Time of Reception (i.e., the RF message arriving at the receive antenna).

The Link Transmit and Receive Equipment requirements are controlled by RTCA DO-260() / EUROCAE ED-102() [37], RTCA DO-282() [42] and EUROCAE ED-108() [4].

3.3.1.2.10 Interface E

Interface E is defined as the time an ADS-B (or TIS-B/ADS-R) Report is delivered to ASSAP. ASSAP requirements are controlled by this document. The ASSAP function will extrapolate the traffic positions to a common time of applicability, within required tolerances, prior to performing application specific calculations and passing the traffic to the CDTI interface (F).

In an integrated architecture, Interface E may not be observable. For example, in an Air Transport installation, it is possible that the ADS-B Receiver will be integrated with the TCAS II equipment that may also implement the ASSAP requirements.

3.3.1.2.11 Interface F

Interface F is defined as the time the ownship and traffic tracks are delivered to the CDTI. For architectures that do not process ownship and traffic data together, the Time of Delivery at interface F might differ.

The latency budget allocated between E and F was based on a feasibility study of implementing ASSAP in TCAS II equipment and supporting legacy equipment upgrades.

3.3.1.2.12 Interface G

Interface G is defined as the Time of Display, i.e., the time when the track information appears on the display.

The CDTI function may translate and rotate the traffic as needed to maintain a smooth and consistent display. The CDTI function is not required to extrapolate the traffic from the ASSAP Time of Applicability to the Time of Display. However, it may be desirable for the ASSAP Time of Applicability (at interface F) to coincide with the Time of Display by design to minimize display latency.

3.3.1.3 Total Latency for ADS-B and ADS-R

The Total Latency for ADS-B and ADS-R is the time difference between the Time of Measurement (TOM) of the source data at the transmitting aircraft (Interface A1) and the time that data are displayed to the user on the receiving aircraft (Interface G).

The additional latency introduced by the ground infrastructure **shall (R3.136)** {new reqmt} be less than the latency required by the most stringent applications in the SBS CONOPS minus the inherent airborne latencies on both ends.

The maximum delay between the time of message received of an ADS-B Message that results in the generation of ADS-R Uplink Messages (Interface D) and the transmission of the first bit of any corresponding broadcast Message on the opposite link technology (Interface D’) **shall (R3.137)** {new reqmt} be less than or equal to 1 second.

The ADS-B to ADS-R transmission latency **shall (R3.138)** {new reqmt} be compensated in the ADS-R horizontal position by linearly extrapolating to the time of transmission.

Note: *It is expected that a Ground Station would be capable of determining the time of transmission of an ADS-R message to within 100 ms.*

The ADS-R Service **shall (R3.139) not** {new reqmt} introduce any additional position error to that which might otherwise be introduced by a linear extrapolation using the instantaneous velocity reported for the target on the other ADS-B data link.

ASSUMP 11: The Total Latency for Ownship position data sources is assumed to be no greater than 1 second from the Time of Measurement (Interface A3) to the time the data is supplied to ASSAP (Interface B3, see Figure 1-1).

The Total Latency for State data in ADS-B and ADS-R **shall (R3.140)** {new reqmt} be no greater than 5.5 seconds from A1 to G to support the applications included in §2.2.1.1 for ADS-B and §2.1.1 for ADS-R. {This requirement is consistent with the ASA MOPS, DO-317A FRAC draft, September 2011, but is less stringent than the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010, which requires 5 seconds.}

The Total Latency for updated ID/Status {from DO-289, §2.4.5.1} information in ADS-B and ADS-R from interface A1 to G **shall (R3.141)** {new reqmt} be no greater than 30 seconds. {This requirement is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010}

The Total Latency for State data in ADS-B and ADS-R from Interface B1 to D **shall (R3.142)** {new reqmt} be no greater than 1.1 seconds.

The Total Latency for State data in ADS-B and ADS-R from Interface D to G **shall (R3.143)** {new reqmt} be no greater than 3.5 seconds.

The Total Latency of measured geometric position data in the aircraft/vehicle receiving ADS-B, ADS-R or TIS-B (interfaces D to E in Figure 3-11) **shall (R3.144)** {new reqmt} be no greater than 0.5 seconds.

3.3.1.4 Navigation Subsystem Total Latency Allocation

ASSUMP 12: The Total Latency allocation for the navigation subsystem that measures the source position and velocity for the ADS-B transmitting aircraft/vehicle is assumed to be no greater than 0.5 seconds from Interface A1 to A4.

ASSUMP 13: The Total Latency allocation from Interface A1 to B1 is assumed to be no greater than 0.9 seconds. {These requirements are consistent with the ASA MOPS DO-317A }

Note: *These subsystem latency allocations are included in the total latency.*

3.3.1.5 TIS-B Subsystem Total Latency Allocation

The TIS-B subsystem latency is the difference between the TOM of the source position data and the time of transmission of the TIS-B Message by the ground radio station, interfaces A2 to D in Figure 1-1.

The latency allocation for the TIS-B ground subsystem **shall (R3.145)** {new reqmt} be no greater than 3.25 seconds to support the applications included in §2.2.1.1. {This requirement is consistent with DO-289, §3.1.1.5, (no number assigned to this requirement), 286R2.5-01, and the FAA Essential Services Specification for SBS, version 2.2, 29 November 2010}

Note: *In the future there may be a need for separate requirements for airborne and/or surface TIS-B.*

The latency for TIS-B Service processing of TIS-B data **shall (R3.146)** {new reqmt} be less than 1.5 seconds as measured from the Ground System Surveillance Sensor Interface B2 (see Figure 1-1) to the start of the TIS-B Message transmission, Interface D.

This requirement applies to services delivered to the airport surface, terminal airspace and en route airspace. There is an allocation of 3.25 seconds from sensor measurement to TIS-B Message transmission. The expected maximum delay associated with getting target measurements from a radar sensor is 1.725 seconds, leaving the balance of time to the TIS-B Service.

The Ground Surveillance Sources Interface to TIS-B transmission latency **shall (R3.147)** {new reqmt} be compensated in the TIS-B horizontal position by linearly extrapolating to the time of transmission.

Note: *It is expected that a Ground Station would be capable of determining the time of transmission of a TIS-B message to within 100 ms.*

The TIS-B Service **shall (R3.148) not** {new reqmt} introduce any additional position error to that which might otherwise be introduced by a linear extrapolation using the instantaneous velocity provided for the target.

3.3.1.6 Latency Compensation Error

The latency compensation error is the residual after the TOM on the transmitting aircraft/vehicle or the Time of Applicability (TOA) of the position data on the receiving aircraft/vehicle has been estimated. The allowable errors in the following requirements are included in the total latency defined above. {The requirements in this section are consistent with the ASA MOPS, DO-317A. The transmit-side latency compensation error is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010, however, the receive-side error is not accounted for in the fPR.}

ASSUMP 14: Since the reports generated by the ADS-B Receive Subsystem have a Time of Applicability, it is assumed that any extrapolation of target data by ASSAP/CDTI utilizes that TOA.

The latency compensation error of measured geometric position data in the aircraft/vehicle transmitting ADS-B (interfaces A1 to D in Figure 3-11) **shall (R3.149)** {new reqmt} be no greater than +0.6 seconds. {reference AC 20-165, and DO-260B, Appendix-U}

The latency over-compensation error of measured geometric position data in the aircraft/vehicle transmitting ADS-B (interfaces A1 to D) **shall (R3.150)** {new reqmt} be limited to 200 ms. {reference AC 20-165, and DO-260B, Appendix-U}

The additional contribution to latency compensation error for retransmitted geometric position data by the ADS-R ground subsystem (interfaces B2 to D in Figure 1-1) **shall (R3.151)** {new reqmt} be no greater than 0.1 seconds. {reference DO-317A, 1.5.1.2.2 and SBS Critical Services Spec}

The latency compensation error of source position data by the TIS-B ground subsystem (interfaces A2 to D in Figure 1-1) **shall (R3.152)** {new reqmt} be no greater than ±0.5 seconds. {reference 286R2.5-02}

The latency compensation error of measured geometric position data (from Interface E to G) **shall (R3.153)** {new reqmt} be no greater than ±500 ms.

3.3.2 ADS-R/TIS-B Service Status Update Interval

The update interval is the time between successive updates of particular information at the receiving aircraft/vehicle.

The update interval of ADS-R or TIS-B Service Status information in the receiving aircraft **shall (R3.154)** {new reqmt} be less than 30 seconds (measured at Interface D). {This requirement is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010}

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3.4 Subsystem Requirements

3.4.1 Subsystem Requirements for ASSAP

ASSAP is the Airborne Surveillance and Separation Assurance Processing component of ASA. ASSAP processes incoming data from Ownship, and other aircraft/vehicles (A/V), and derives information for display on the CDTI. Flight crew command and control inputs that affect application functions are also processed by ASSAP. In the future, ASSAP is expected to provide alerting and guidance information to the flight crew via the CDTI.

The two major functions of ASSAP are *surveillance processing* and *applications processing*. Functional requirements for ASSAP are described in §3.4.1.4.

<u>Surveillance processing:</u>

- Establishes tracks from ADS-B, ADS-R, and TIS-B traffic reports
- Cross-references traffic from different surveillance sources (ADS-B, ADS-R, TIS-B, and TCAS)
- Estimates track state (e.g., position, velocity), and track quality
- Deletes tracks that are beyond the maximum allowable coast time for any ASA applications

<u>Applications processing:</u>

- Determines the appropriateness of track information for various applications, and forwards the track data to the CDTI
- May performs alerting functions in future applications
- May derive guidance information in future applications

Each ASA transmit participant should input to ASSAP the highest quality state data that is available on-board; this information should be the same as that used for ADS-B transmission. ASSAP assesses Ownship performance and transmitted data quality and assesses received traffic data quality as specified in Table 2-3 to determine if an active application can be supported.

Figure 3-13 summarizes ASSAP input / output interfaces to other subsystems and indicates the sections where the interface, functional, and performance requirements can be found in this document.

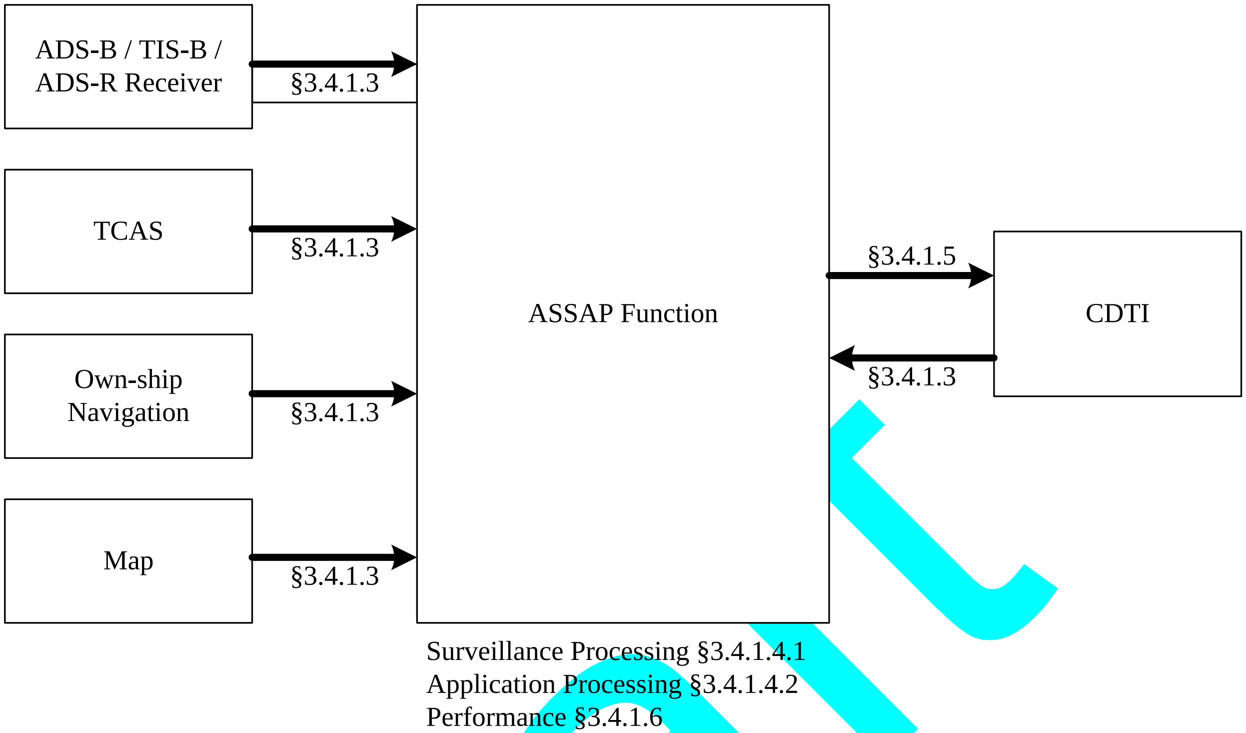

Figure 3-13: ASSAP Input / Output and Requirement Section Summary

3.4.1.1 Definitions Key to Understanding ASSAP

The following are key definitions related to the understanding of ASSAP. These and other definitions are provided in Appendix A.

Correlation: The process of determining that a new measurement belongs to an existing track.

Estimation: The process of determining a track's state based on new measurement information

Extrapolation: The process of moving a track's state forward in time based on the track's last estimated kinematic state.

TCAS Alert status: The status of the TCAS track, if applicable, from the TCAS system. The four states are: Resolution Advisory (RA), Traffic Advisory (TA), Proximate, and other.

Track: A sequence of time-tagged measurements and state information relating to a particular aircraft or vehicle. The track may be a simple list file of A/V position and time data extrapolated to a common time for processing and display, or may include track estimation and Kalman filtering.

<u>Track State:</u> The basic kinematic variables that define the state of the aircraft or vehicle of a track, e.g., position, velocity, acceleration.

3.4.1.2 General Requirements

When integrated with TCAS systems the ASSAP function **shall (R3.155) not** {new reqmt} interfere with TCAS guidance to the flight crew.

3.4.1.3 Input Interface Requirements

ASSAP provides the central processing for ASA and interfaces with many other avionics subsystems. Depending on the class of aircraft, either EVAcq or AIRB defines the basic use of ASA for enhanced traffic situational awareness, and support for this application is the minimum requirement for all ASA implementations. The remaining applications (VSA, ITP, and SURF) are optional. Although VSA, ITP, and SURF applications are optional, when they are implemented, the requirements designated for these applications must be met.

ASSAP **shall (R3.156)** {from 289R3.213} provide all input interfaces to support the minimum requirements for all installed applications as indicated in Table 3-29 by a dot (•).

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3960 **Table 3-29: ASSAP Input Interface Requirements**

Source	Info Category	Information Element [6]	EVAcq	AIRB	VSA	ITP	SURF
ADS-B / ADS-R / TIS-B Receiver	**Aircraft State Data**	Time Of Applicability	●	●	●	●	●
		Latitude (WGS-84)	●	●	●	●	●
		Longitude (WGS-84)	●	●	●	●	●
		Geometric Altitude [1, 9]	●	●	●	●	●
		Air / Ground State	●	●	●	●	●
		North Velocity While Airborne [9]	●	●	●	●	●
		East Velocity While Airborne [9]	●	●	●	●	●
		Ground Speed While on the Surface		●	●	●	●
		Heading (true / mag) or Ground Track While on the Surface	●	●	●	●	●
		Pressure Altitude [9]	●	●	●	●	●
		Vertical Rate [9]	●	●	●	●	●
		Navigation Integrity Category (NIC)	●	●	●	●	●
ADS-B / ADS-R / TIS-B Receiver (continued)	**ID / Status**	ADS-B Link Version Number	●	●	●	●	●
		Participant Address	●	●	●	●	●
		Address Qualifier	●	●	●	●	●
		Call Sign / Flight ID		●	●	●	●
		A/V Length and Width Codes [8, 9]					●
		Emitter Category		●	●	●	●
		Emergency / Priority Status [7]	●	●	●	●	●
		Navigation Accuracy Category for Position (NAC_P)	●	●	●	●	●
		Navigation Accuracy Category for Velocity (NAC_V)	●	●	●	●	●
		Geometric Vertical Accuracy (GVA) [1, 9]	●	●	●	●	●
		Surveillance Integrity Level (SIL)		●	●	●	●
		System Design Assurance (SDA)	●	●	●	●	●
		True/Magnetic Heading Reference	●	●			●
		TIS-B / ADS-R Service Status [2]	●	●	●	●	●
TCAS Target	TCAS related data[5]	Alert Status	●	●	●	●	●
		Range	●	●	●	●	●
		Bearing	●	●	●	●	●
		Pressure Altitude [3]	●	●	●	●	●
		Altitude Rate or Vertical Sense	●	●	●	●	●
		Mode S Address[3]	●	●	●	●	●
		Track ID	●	●	●	●	●

Source	Info Category	Information Element [6]	EVAcq	AIRB	VSA	ITP	SURF
Navigation	Ownship state data	Time of Applicability	●	●	●	●	●
		Horizontal Position	●	●	●	●	●
		Horizontal Velocity	●	●	●	●	●
		Geometric Altitude[1]	●	●	●	●	●
		Pressure Altitude	●	●	●	●	●
		Ground Speed (on surface)				●	
		Heading, True [4]	●	●	●	●	●
		Track Angle, True				●	
		A/V Length and Width Codes[8]					●
	Ownship quality	Position Integrity Containment Region		●	●	●	●
		Source Integrity Level		●	●	●	●
		Horizontal Position Uncertainty	●	●	●	●	●
		Vertical Position Uncertainty [1]	●	●	●	●	●
		Velocity Uncertainty	●	●	●	●	●
	ID / Status	24 bit Address	●	●	●	●	●
		Air / Ground State	●	●	●	●	●
CDTI	Flight Crew Inputs	Application Selection	●	●	●	●	●
		Selected Traffic	●	●	●	●	●
		Designated Traffic	●	●	●	●	●
	Map Database	Airport Map Status	●	●	●	●	●

● = Required

Notes for Table 3-29:

1. *When geometric altitude is used to determine relative altitude.*
2. *For systems that don't receive information from TCAS.*
3. *This information requires a change to the standard TCAS bus outputs defined in ARINC 735A/B [1] that currently does not provide the Mode S address code, nor does it necessarily output pressure altitude.*
4. *For systems that receive information from TCAS or determine relative bearing for traffic.*
5. *Required if TCAS is present in the configuration and an integrated TCAS/ASA traffic display is used. These outputs are expected to be supplied by current TCAS installation.*
6. *Each future application will add columns for minimum requirement.*
7. *When used to display the Emergency/Priority Status.*
8. *When used to display the physical extent of the aircraft.*
9. *Not required for surface vehicles.*

3.4.1.4 ASSAP Functional Requirements

ASSAP functional requirements are broken into surveillance processing requirements (§3.4.1.4.1) and applications processing requirements (§3.4.1.4.2).

3.4.1.4.1 ASSAP Surveillance Processing Requirements

ASSAP surveillance processing function receives information for traffic A/V's from various surveillance sources, correlates the data, registers the data, and outputs a track file consisting of state and other information about each A/V under track. Requirements for the surveillance sub-function follow. Note that the tracking and correlation functions make extensive use of the data that is provided in state data (Table 3-29).

ASSAP **shall (R3.157)** {derived from 289R3.177} acquire all State data necessary to generate tracks for A/Vs and Ownship.

ASSAP may receive A/V data from different surveillance sources.

ASSAP **shall (R3.158)** {from 289R3.169} perform a tracking function on each traffic A/V.

ASSAP **shall (R3.159)** {from 289R3.188} extrapolate the target horizontal position (i.e., latitude and longitude), for tracks of airborne traffic for which a position update has not been received, to a common time reference prior to providing information to the CDTI.

Note: *A linear extrapolation is expected to be used to compensate for any delays incurred leading up to the time of transmission. Extrapolation is only performed on targets determined to be airborne. The pressure altitude should not be extrapolated since the altitude rate accuracy may induce larger altitude errors than the provided in the original data.*

ASSAP **shall (R3.160)** {new reqmt} minimize position error due to extrapolation.

Note: *An acceptable means of this would be linear extrapolation using the instantaneous velocity reported for the target.*

ASSAP **shall (R3.161)** {new reqmt} maintain tracks for multiple A/Vs.

ASSAP may receive A/V data for the same A/V from different surveillance sources.

The ASSAP tracking function **shall (R3.162)** {from 289R3.172} include a correlation function that associates traffic data from any surveillance sources that relate to the same A/V's track to minimize the probability of processing and displaying duplicate A/Vs.

If the ASSAP determines that multiple source tracks correlate, the best quality source track **shall (R3.163)** {from 289R3.72} be used.

The ASSAP tracking function **shall (R3.164)** {from 289R3.178} terminate a track when the maximum coast interval or data age (see RTCA DO-317A [49], Table 2-4) has been exceeded for all of the applications for which the track is potentially being used.

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3.4.1.4.2 ASSAP Application Processing Requirements

The ASSAP will determine if the available data, quality, and track information is sufficient to support the minimum requirements display an A/V on the CDTI, and to run the installed applications.

If an A/V track is being surveilled by multiple sources, the determination of acceptability for applications should be based on the track quality as derived by ASSAP, rather than on quality of any individual source.

If the sole surveillance source of information provided to the ASSAP for a given target is ADS-B, ADS-R, or TIS-B, the track quality assessment **shall (R3.165)** {from 289R3.196} be based on the surveillance quality indicators (e.g., NIC, NAC_P, NAC_V, SIL).

ASSAP track quality **shall (R3.166)** {derived from 289R3.185-A} be compared with minimum performance requirement values for each applications.

ASSAP **shall (R3.167)** {from 289R2.27} assess the ability of Ownship and traffic targets to support the active applications.

ASSAP **shall (R3.168)** {from 289R3.187} make ASSAP track reports available to the CDTI for all active applications.

ASSAP **shall (R3.169)** {from 289R3.188} deliver track reports to the CDTI for all aircraft of sufficient quality for at least EVAcq or AIRB.

Note: *Precise conditions under which airborne and surface traffic is to be displayed and filtered is developed in the ASA System MOPS, the latest version of RTCA DO-317( ).*

The ASSAP track report **shall (R3.170)** {from 289R3.198} indicate if the track's quality is insufficient for EVAcq or AIRB.

3.4.1.5 Output Interface Requirements to CDTI

Information elements that are required as inputs to the ASSAP are also required to be available as outputs from the ASSAP to the CDTI to support the installed applications.

Some CDTIs may be implemented on existing NAV displays that already have their Ownship position data sources input directly. In that architecture, the interfaces from the ASSAP to the CDTI for those data sources are not a minimum requirement. In this case, the CDTI would have to make sure that the Ownship quality/integrity thresholds for the associated applications are met to perform each application. Alternatively, the necessary information could be sent from the CDTI to the ASSAP.

ASSAP **shall (R3.171)** {new reqmt} provide all output interfaces to the CDTI to support the minimum requirements for all installed applications

Note: *No longer providing the data element (e.g., label or data word) may be another method of inferring valid/invalid status.*

3.4.1.6 ASSAP Performance Requirements

The ASSAP function **shall (R3.172)** {new reqmt} provide a traffic capacity sufficient to support the active applications.

Note: *A capacity of at least 60 tracks (30 airborne and 30 surface) is sufficient for the initial applications covered in these MASPS.*

ASSAP outputs **shall (R3.173)** {new reqmt} be sent to the CDTI at a rate sufficient to support the active applications.

Note: *An output rate of once per second is sufficient to support the applications covered in these MASPS.*

3.4.2 Subsystem Requirements for CDTI

Note: *The requirements in this section are extended in the latest version of the ASA MOPS, RTCA DO-317() [49].*

3.4.2.1 General CDTI Requirements

The CDTI **shall (R3.174)** {from 289.Section 2.4.3.5}{from 317A. Section 1.5.2.2} be presented on one or more of the following:

1. A standalone display dedicated to traffic information only.

2. A shared/multi-function display.

3. An Electronic Flight Bag (EFB).

The CDTI **shall (R3.175)** {from 317A.Section 1.2.2.2, 2.3.1} include a Traffic Display, as defined in Appendix A.

The CDTI **shall (R3.176)** {new reqmt} satisfy all applicable requirements listed in this document in all flight environments (e.g., expected temperatures and pressures) and operating areas (e.g., domestic and oceanic airspaces) for which it is intended.

Note: *For example, in order to satisfy this requirement fully, CDTI's intended for operation over or in the vicinity of the geographic poles would have to include an adequate provision for representing directionality of displayed traffic elements. A suitable coordinate transformation may be required and could be allocated to the ASSAP or the CDTI function.*

The operating range of display luminance and contrast **shall (R3.177)** {from 317A.3021} be sufficient to ensure display readability through the full range of normally expected flight deck illumination conditions.

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CDTI information should {from 317A.Section 2.3.3.1} be discernable, legible, and unambiguous within all flight environments (e.g., ambient illumination), even when displayed in combination with other information (e.g., electronic map).

The CDTI and associated alerting should {from 317A.Section 1.5.2.4} be properly integrated with other display functions and should not interfere with critical functions or other alerting.

The CDTI should {from 289.Section 2.4.3.5} be designed so as to maximize usability, minimize flight crew workload, and reduce flight crew errors.

The CDTI display should {from 289.Section 2.4.3.5} be consistent with the requirements of current airborne display standards.

If non-traffic information is integrated with the traffic information on the display, the directional orientation, range, and Ownship position **shall (R3.178)** {from 317A.3117} be consistent among the different information sets.

Any probable failure of the CDTI **shall (R3.179)** {from 317A.7005} not degrade the normal operation of equipment or systems connected to it.

The failure of interfaced equipment or systems **shall (R3.180)** {from 317A.7006} not degrade normal operation of the CDTI.

3.4.2.2 Time of Applicability

The CDTI **shall (R3.181)** {new reqmt} display all traffic and ownship state information extrapolated to a common time of applicability.

Note: *ASSAP delivers all traffic state data extrapolated to a common time of applicability. In some architectures, ASSAP will also deliver ownship state information extrapolated to the same time of applicability.*

3.4.2.3 Information Integrity

The CDTI **shall (R3.182)** {from 289.R3.243} {from 317A.3014} display information with an integrity that meets the requirements of the installed applications.

3.4.2.4 Applications Supported

The CDTI **shall (R3.183)** {from 317A.3000} support the AIRB or the EVAcq application.

Note: *Other applications are optional.*

The CDTI may {from 317A.2.3.1} support any subset of the following additional applications:

1. Basic Surface Situation Awareness (SURF).

2. Visual Separation on Approach (VSA).
3. In-Trail Procedures (ITP).

The CDTI **shall (R3.184)** {new reqmt} not present conflicting information or guidance.

Note: *Installations supporting multiple applications or functional capabilities may require design considerations to ensure a clearly defined management of outputs from multiple applications or functional capabilities.*

3.4.2.5 Units of Measure

The CDTI should {from 289R3.258} portray data using units of measure that are consistent with the design of the flight deck in which it is installed.

The CDTI **shall (R3.185)** {new reqmt} portray all data using consistent units of measure and reference frames.

3.4.2.6 Information Exchange with ASSAP

The CDTI **shall (R3.186)** {from 317A.3015} accept all information provided to it by ASSAP.

The CDTI **shall (R3.187)** {from 317A.2045} provide ASSAP the information needed for the activation and deactivation of applications, including those that operate on specifically selected and/or designated traffic.

3.4.2.7 Traffic Symbols

The Traffic Display **shall (R3.188)** {from 289.R3.236} {from 317A.3035} display one traffic symbol for each traffic report received from ASSAP that meets the traffic display criteria for the active applications subject to the maximum number of traffic symbols.

The Traffic Display **shall (R3.189)** {new reqmt} be capable of displaying the minimum number of traffic symbols commensurate with the requirements of the installed applications.

3.4.2.8 TCAS Integration

On TCAS-integrated CDTI systems, the CDTI **shall (R3.190)** {new reqmt} prioritize the display of TCAS information in such a manner as to preserve the integrity of the safety objectives for TCAS.

In order to provide more complete traffic situational awareness, the CDTI should {from 289.Section 2.2.2.5.1.15}, on aircraft also equipped with TCAS, integrate the display of TCAS information.

3.4.2.9 Multi-Function Display (MFD) Integration

Symbols, colors, and other encoded information that have a certain meaning in the traffic display function should not {from 317A.Section 2.3.8.1} have a different meaning in another MFD function.

The MFD system should {from 317A.Section 2.3.8.1} provide the capability to enable and disable display of traffic information (i.e., to overlay traffic or turn traffic information off).

3.4.2.10 Failure Annunciation

The CDTI **shall (R3.191)** {new reqmt} be capable of annunciating all failure / abnormal conditions of the CDTI or its inputs that affect the proper operation of the CDTI or the ability to conduct applications, including the loss of surveillance data needed for an application.

3.4.2.11 Suitability of Traffic for Applications

If any additional applications are installed (more stringent than AIRB or EVAcq), the CDTI system **shall (R3.192)** {from 317A.3052} have a means to determine the traffic's application capability with respect to each installed application.

3.4.2.12 Warnings and Alerts

The CDTI **shall (R3.193)** {new reqmt} provide sufficiently and appropriately salient warnings and alerts for all warning and alert conditions.

The CDTI **shall (R3.194)** {new reqmt} provide sufficient awareness as to the causes for the warnings and alerts.

Aural alerts **shall (R3.195)** {from 317A.3103} be audible and distinguishable in all expected flight deck ambient noise conditions.

CDTI alerts should {from 289.Section 2.3.6.5} be consistent with, and capable of being integrated into the flight deck alerting system, giving proper priority to alerts with regard to safety of flight.

3.4.2.13 Display Configuration

The CDTI **shall (R3.196)** {new reqmt} be configurable as necessary to support the installed applications.

The CDTI **shall (R3.197)** {new reqmt} provide a sufficient set of controls to enable and disable all configurations, enable and disable all installed applications and to exercise all of its features.

The CDTI **shall (R3.198)** {new reqmt} provide a sufficient set of indications to portray the CDTI's current configuration and the status of installed applications in a readily appreciable manner.

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3.4.2.14 Accessibility of Controls

The CDTI **shall (R3.199)** {new reqmt} be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the operation of the aircraft or the reliability of the equipment.

3.4.2.15 Information Displayed

The CDTI **shall (R3.200)** {new reqmt} be capable of displaying the types of information needed for the execution of the installed applications.

Note: *Extensive, detailed requirements can be found in the latest version of the ASA Systems MOPS, RTCA DO-317() [49].*

3.4.2.16 General CDTI Symbol Requirements

Each CDTI symbol **shall (R3.201)** {from 317A.3022} be identifiable and distinguishable from other CDTI symbols.

The shape, color, dynamics, and other symbol characteristics should {from 317A.Section 2.3.3.4} have the same meaning within the CDTI.

CDTI symbol modifiers should {from 317A.Section 2.3.3.4} follow rules that are consistent across the symbol set.

If symbols are used to depict elements that have standard symbols (such as navigational fixes), the CDTI should {from 289.Section 3.3.3.1.2} use symbols that are consistent with established industry standards.

The CDTI system should {from 317A.Section 2.3.8} be consistent with the rest of the flight deck in terms of color, standardization, automation, symbology, interaction techniques and operating philosophy.

3.4.2.17 CDTI Design Assurance

The CDTI **shall (R3.202)** {new reqmt} be designed such that the probability of providing misleading information and the probability of loss of function are acceptable for the most stringent application supported.

3.4.2.18 Ownship State Information

The CDTI may receive ownship state (horizontal and vertical position, direction and speed) from ASSAP, in which case ASSAP also provides validity status of that information. Alternatively, the CDTI may receive ownship state information from other onboard sources. In the latter case, the CDTI **shall (R3.203)** {new reqmt} receive valid status of the ownship information from the onboard sources and/or perform an appropriate validation of the information.

3.4.3 Subsystem Requirements for ADS-B

This section describes ADS-B system requirements. Specifications in this document are intended to be design independent. Surveillance coverage as well as information exchange requirements for the defined equipage classes are contained in this section. Additionally, performance requirements including report accuracy, update period and acquisition range are provided. Other performance considerations are provided including ADS-B link capacity, ADS-B medium requirements and ADS-B quality of service. Additional information on design considerations are contained in appendices. Appendix D discusses antenna considerations and the use of receive antenna pattern shaping to increase aircraft-to-aircraft forward sector operational range. Acquisition and tracking considerations are discussed in Appendix F. Additional design considerations and analysis related to ADS-B equipage class capabilities is contained in appendices in RTCA DO-242A [27].

3.4.3.1 ADS-B Surveillance Coverage

Air-to-air coverage requirements for illustrative operational scenarios were given in Table 2-4, and values associated with current ATS surveillance capabilities were summarized in Table 2-5. Transmitter and receiver requirements follow from these coverage requirements. Ideally, all airborne participants would have the same transmitter power and same receiver sensitivity. Recognizing, however, that lower equipage costs may be achieved with lower transmit power and receiver sensitivity, surveillance coverage requirements are based on minimum acceptable capability. Users interested in a certain level of operational capability can thus select an equipage class appropriate to their needs (see Table 3-1).

ADS-B equipage classes summarized in Table 3-1 **shall (R3.204)** {from 242AR3.1} provide the air-to-air coverage specified in Table 3-30. The stated ranges are the basis for the indicated relative effective radiated power (ERP) and the receiver sensitivity requirement for each transmit unit.

Since many users will share the same airspace, and all must be seen by ATS, all A, B, and C equipage classes must be interoperable. The ERP and minimum signal detection capabilities **shall (R3.205)** {from 242AR3.2} support the associated pair-wise minimum operational ranges listed in Table 3-31. Broadcast only aircraft (class B0 and B1) **shall (R3.206)** {from 242AR3.3} have ERP values equivalent to those of class A0 and A1, respectively, as determined by own aircraft maximum speed, operating altitude, and corresponding coverage requirements. Ground vehicles operating on the airport surface (class B2) **shall (R3.207)** {from 242AR3.4} provide a 5 NM coverage range for class A receivers. If required due to spectrum considerations, ADS-B transmissions from ground vehicles (class B2) **shall (R3.208)** {from 242AR3.5} be automatically prohibited when those vehicles are outside the surface movement area (i.e., runways and taxiways). ERP for these vehicles may thus be as low as -12 dB relative to class A1. Fixed obstacle (class B3) broadcast coverage **shall (R3.209)** {from 242AR3.6} be sufficient to provide a 10 NM coverage range from the location of the obstacle.

Following is the rationale for the powers and ranges in Table 3-30 and Table 3-31. Given the air-to-air ranges from Table 2-4, and repeated in Table 3-30, an acceptable range of relative transmitter power was assumed, and appropriate receiver sensitivities were then derived, based on the 90th percentile Minimum Trigger Level (MTL). From these normalized transmitter power and receiver sensitivity values, the interoperability ranges shown in Table 3-31 were derived. An omni-directional aircraft transmit antenna is required for ATS support. While omni-directional receive antennas will generally be employed, a higher gain receive antenna may be used to increase coverage in the forward direction for extended range air-to-air applications (at the expense of reduced coverage in other directions). Appendix E discusses the impact of this directional antenna on alert time and shows that a directional aircraft receive antenna gain increase is limited to about 4 dB. When determining absolute power and sensitivity for the operational ranges given in Table 3-30, it should be noted that the target should be acquired and under firm track at the indicated ranges. This implies that an additional margin for acquisition time is required. The ranges specified in Table 3-30 and Table 3-31 are minimum requirements; other applications may require longer ranges.

Ground receiver only subsystem (class C1) coverage examples are given in Table 2-5. Since en route air-ground ranges are longer than those for air-to-air, some ATS receivers must be more sensitive than airborne receivers. This need may be met with the aid of higher gain ground receive antennas. It is beyond the scope of these MASPS to specify ground receiver sensitivities (Class C).

<u>Table 3-30:</u> Operational Range and Normalized Transmit/Receive Parameters by Interactive Aircraft Equipage Class

Equipage		Required Range (NM)	Transmit ERP relative to P_0 (dB)	Receive Sensitivity relative to S_0 (dB)
Class	**Type**			
A0	Minimum	10	>= -2.5	+3.5
A1	Basic	20	0	0
A2	Enhanced	40	+3	-3
A3	Extended	90	<=+6	-7
A3+ (1)	Extended Desired	120	<=+6	-9.5

For A3 equipment, the reception range **shall (R3.210)** {new reqmt} be as follows:

a. in the forward direction, 90 NM;
b. in the aft direction, 40 NM;
c. 45 degrees to port direction, and starboard of the own aircraft's heading, 64 NM;
d. 90 degrees to port and starboard of own aircraft's heading, 45 NM (see Appendix E);

<u>Note:</u> *For A3+ equipment, the 120 NM desired range applies in the forward direction. The desired range aft is 42NM. The desired range 90 degrees to port and starboard is 85 NM.*

Table 3-31: Interoperability Ranges in NM for Aircraft Equipage Class Parameters Given in Table 3-30

Rx Aircraft → **Tx Aircraft ERP**	**A0 Minimum (S_0+3.5dB)**	**A1 Basic (S_0)**	**A2 Enhanced (S_0-3dB)**	**A3 Expanded (S_0-7dB)**	**A3+ Expanded Desired (S_0-9.5dB)**
A0: Minimum (P_0-2.5dB)	10	15	21	34	45
A1: Basic (P_0)	13	20	28	45	60
A2: Enhanced (P_0+3dB)	18	28	40	64	85
A3: Extended (P_0+6dB)	26	40	56	90	120
A3+: Extended Desired (P_0+6dB)	26	40	56	90	120

3.4.3.2 ADS-B Information Exchange Requirements by Equipage Class

Subsystems must be able to (1) broadcast at least the minimum set of data required for operation in airspace shared with others, and (2) receive and process pair-wise information required to support their intended operational capability. Each equipage class **shall (R3.211)** {from 242AR3.7} meet the required information broadcast and receiving capability at the indicated range to support the capability indicated in Table 3-32 and Table 3-33.

The rationale for the requirements in Table 3-32 is as follows. Column 1 of Table 3-32 combines the equipage classes (which are based on user operational interests) from Table 3-1 with the required ranges given in Table 3-30. Information exchange requirements by application were taken from Table 2-3 to determine the broadcast and receive data required for each equipage class (column 2 of Table 3-32 and Table 3-33). A correlation between the equipage class and the ability of that class to support and perform that application was done next. (The determination of the information exchange ability of an equipage class to support a specific application is determined by the information transmitted by that equipage class, while the ability to perform a specific application is determined by the ability of that equipage class to receive and process the indicated information.)

<u>Table 3-32:</u> Interactive Aircraft/Vehicle Equipage Type Operational Capabilities

	Domain →		Terminal, En Route, Oceanic								Approach		Airport Surface	
Equipage Class ↓	**Data Required to Support Operational Capability**		**R ≤10 NM** e.g., Enhanced Visual Acquisition		**R ≤20 NM**		**R ≤40 NM**		**R ≤90 NM**		**R ≤10 NM** e.g., Enhanced Visual Approach		**R ≤5 NM** e.g., Airport Surface Situation Awareness	
	Transmit	Receive	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Perform
A0 Minimum R≤10 NM	SV MS	SV MS	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes
A1 Basic R≤20 NM	SV MS	SV MS	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
A2 Enhanced R≤40 NM	SV MS TS	SV MS TS	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
A3 Extended R≤90 NM	SV MS TS	SV MS TS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

<u>Notes:</u>

1. *SV= State Vector Report; MS = Mode Status Report; TS = Target State Report.*
2. *A transmitting ADS-B participant <u>supports</u> an application by broadcasting the required data that receiving ADS-B participants need for that application.*
3. *A receiving ADS-B participant <u>performs</u> an application by processing received messages from transmitting ADS-B participants that support that application.*
4. *Operation in airspace with high closure rates may require longer range.*
5. *Class A2 and A3 users may equip for low visibility taxi following.*
6. *Class A1 equipment may optionally support TS Reports.*
7. *MS reports contain time-critical report elements that, when their values change, need to be updated at higher rates than that of the MS Reports. (See §3.5.1.4.1, for details.)*

Table 3-33: Broadcast and Receive Only Equipage Type Operational Capabilities

	Domain →		**Terminal, En Route, and Oceanic / Remote Non-Radar**								**Approach**		**Airport Surface**	
Equipage Class ↓	**Data Required to Support Operational Capability**		**R ≤ 10 NM** e.g., Enhanced Visual Acquisition		**R ≤ 20 NM**		**R ≤ 40 NM**		**R ≤ 90 NM**		**R ≤ 10 NM** e.g., Enhanced Visual Approach		**R ≤ 5 NM** e.g., Airport Surface Situation Awareness	
	Transmit	Receive	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form
B0 Aircraft R≤10 NM	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B1 Aircraft R≤20 NM	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B2 Ground Vehicle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B3 Fixed Obstacle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
C1 ATS En route & Terminal	No	SV MS TS	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No
C2 Approach & Surface	No	SV MS TS	No	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes
C3 Flight Following	No	SV MS	No	Yes	No	No	No	No	No	No	No	No	No	No

Notes:

1. *SV= State Vector; MS = Mode Status; TS = Target State Report*
2. *A transmitting ADS-B participant supports an application by broadcasting the required data that receiving ADS-B participants need for that application.*
3. *A receiving ADS-B participant performs an application by processing received messages from transmitting ADS-B participants that support that application.*

3.4.3.3 ADS-B Data Exchange Requirements

3.4.3.3.1 Report Accuracy, Update Period and Acquisition Range

The subparagraphs below specify the report accuracy, update period, and acquisition range requirements for state vector, modes status, and specific on-condition reports. For each of these subparagraphs, report acquisition **shall (R3.212)** {from 242AR3.8} be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant. In order to meet these requirements, the receiving participant must begin receiving messages at some range outside the minimum range for a given application. Appendix F illustrates examples of expected acquisition time for state vector, mode-status, and on-condition reports as a function of message period and probability of receipt. Appendix F also treats the necessary acquisition time for segmented state vector messages.

3.4.3.3.1.1 State Vector Report Acquisition, Update Interval and Acquisition Range

State vector (SV) report accuracy, update period and acquisition range requirements are derived from the sample scenarios of section 2, and are specified in Table 3-34. The state vector report **shall (R3.213)** {from 242AR3.9} meet the update period and 99 percentile update period requirements for each operational range listed. The rationale for these values is given in RTCA DO-242A, Appendix J. The formulation in RTCA DO-242A [27], Appendix J examines the loss of alert time resulting from data inaccuracies, report update interval, and probability of reception. The scope of the analysis was not sufficient to guarantee that the specific operations considered will be supported. Several range values are specified in Table 3-34 because the alert time requirements are more demanding for short range than they are for surveillance of targets at longer ranges. The first value is based on minimum range requirements. Beyond this range, update period and/or receive probability may be relaxed for each sample scenario, as given by the other values.

For each of the scenarios included in Table 3-34, the state vectors from at least 95% of the observable user population (radio line-of-sight) supporting that application **shall (R3.214)** {from 242AR3.10} be acquired and achieve the time and probability update requirements specified for the operational ranges.

ASSUMP 15: The state vector report is constantly changing and is important to all applications, including the safety critical ones. Algorithms designed to use the state vector reports will assume that the information provided is correct. (Some applications may even require that the information is validated before using it.)

Note: *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for closest point of approach. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

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Required ranges for acquisition **shall (R3.215)** {from 242AR3.11} be as specified in Table 3-34: (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3).

Table 3-34 shows accuracy values in two ways: one describing the ADS-B Report information available to applications, and the other presenting the error budget component allocated to ADS-B degradation of this information. The ADS-B system **shall (R3.216)** {from 242AR3.12} satisfy the error budget requirements specified in the table in order to assure satisfaction of ADS-B Report accuracies. Degradation is defined here to mean additional errors imposed by the ADS-B system on position and velocity measurements above the inherent navigation source errors. The errors referred to in this section are specifically due to ADS-B quantization of state vector information, and other effects such as tracker lag. ADS-B timing and latency errors are treated as a separate subject under heading §3.4.3.3.2. The maximum errors specified in Table 3-34 are limited to contributions from the following two error sources:

- Quantization errors. The relationship between the quantization error and the number of bits required in the ADS-B Message are described in Appendix D. This discussion also treats the effect of data sampling time uncertainties on report accuracy.

- Errors due to a tracker. The ADS-B system design may include a smoothing filter or tracker as described in Appendix D. If a smoothing filter or tracker is used in the ADS-B design, the quality of the reports **shall (R3.217)** {from 242AR3.13} be sufficient to provide equivalent track accuracy implied in Table 3-34 over the period between reports, under target centripetal accelerations of up to 0.5g with aircraft velocities of up to 600 knots. Tracker lag may be considered to be a latency (§3.3.1).

<u>Table 3-34:</u> SV Update Interval and Acquisition Range Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**				**Approach ↓**	**Airport Surface ↓**
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**	**R ≤ 10 NM**	**(R ≤ 5 NM)**
Equipage Class →	**A0-A3 B0, B1, B3**	**A1-A3 B0, B1, B3**	**A2-A3**	**A3**	**A1-A3**	**A0-A3 B0, B1, B3**
Example Applications →	EVAcq	AIRB, VSA, TSAA	FIM	FIM, ITP	VSA, CSPA	SURF, SURF-IA
Required 95th percentile SV Acquisition Range	10 NM	20 NM	40 NM (Note 4) (50 NM desired)	90 NM (Note 2) (120 NM desired)	10 NM	5 NM
Required SV Nominal Update Interval (95th percentile) (Note 1)	≤ 3 s (3 NM) ≤ 5 s (10 NM) (Note 3)	≤ 5 s (10 NM) (1 s desired,) ≤ 7 s (20 NM)	≤ 7 s (20 NM) ≤ 12 s (40 NM)	≤ 12 s	≤ 1.5 s (1000 ft runway separation) ≤ 3 s (1s desired) (2500 ft runway separation)	≤ 1.5 s
Required 99th Percentile SV Received Update Period	≤ 6s (3 NM) ≤ 10 s (10 NM) (Note 3)	≤ 10 s (10 NM) ≤ 14 s (20 NM)	≤ 14 s (20 NM) ≤ 24 s (40 NM)	≤ 24 s	≤ 3s (1000 ft runway separation) (1s desired) ≤ 7s (2500 ft runway separation)	≤ 3 s

<u>Notes for Table 3-34:</u>

1. *Refer to analysis in Appendix F.*

2. *Air-to-air ranges extending to 90 NM were originally intended to support the application of Delegated Separation and Self Separation, Delegated Separation in Oceanic/Low Density En Route Airspace, described as "Cooperative Separation" in RTCA DO-242A [27], §2.2.2.6. It is noted in RTCA DO-242A [27], §2.2.2.6, in connection with Table 2-4, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas.*

3. *Requirements for applications at ranges less than 10 NM are under development. The 3-second update period is required for aircraft pairs with horizontal separation less than [1.1 NM] and vertical separation less than [1000 feet]. The 3 second update period is also required to support ACM for aircraft pairs within 3 NM lateral separation and 6000 feet vertical separation that are converging at a rate of greater than 500 feet per minute vertically or greater than 6000 feet per minute horizontally. The update rate can be reduced to once per 5 seconds (95%) for aircraft pairs that are not within these geometrical constraints and for applications other than ACM. Requirements for ACM are under development. Requirements for future applications may differ from those stated here.*

4. *These values are based on the scenario in RTCA DO-242A [27], §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.3.1.2 Mode Status Acquisition, Update Interval and Acquisition Range

Mode Status (MS) acquisition range requirements are derived from the sample scenarios of Chapter 2, and are specified in Table 3-35. For each of the equipage classes included in Table 3-35, the Mode Status reports from at least 95% of the observable (radio line of sight) population **shall (R3.218)** {from 242AR3.14-A} be acquired at the range specified in the "Required 95th Percentile Acquisition Range" row of Table 3-35 (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3). Likewise, for each of the equipage classes included in Table 3-35, the Mode Status reports from at least 99% of the observable (radio line of sight) population **shall (R3.219)** {from 242AR3.14-B} be acquired at the reduced range specified in the "Required 99th Percentile Acquisition Range" row of Table 3-35.

Note: *As requirements mature for applications that require MS Reports, the required probably of acquisition at specified ranges may change. It is possible that these requirements may be more stringent in later versions of these MASPS.*

Mode Status (MS) update intervals are not specified directly. Only the minimum acquisition ranges are specified. From these minimum ranges, combinations of update intervals and receive probabilities for MS can be derived for media specific ADS-B implementations.

Table 3-35: MS Acquisition Range Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**				**Approach ↓**	**Airport Surface ↓**
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**	**R ≤ 10 NM**	**(R ≤ 5 NM)**
Equipage Class →	**A0 - A3 B0 - B3**	**A1 - A3 B0 - B3**	**A2 - A3**	**A3**	**A1 - A3**	**A0 - A3 B0 - B3**
Example Applications → (Note 1)	EVAcq	AIRB, VSA, TSAA	FIM	FIM, ITP	VSA, CSPA	SURF, SURF-IA
Required 95th percentile MS Acquisition Range	10 NM	20 NM	40 NM (Note 5) (50 NM desired)	90 NM (Notes 2) (120 NM desired)	10 NM	5 NM
Required 99th percentile MS Acquisition Range (Notes 3, 4)	8 NM	17 NM	34 NM (Note 5)	n/a	n/a	n/a

n/a: not applicable.

Notes for Table 3-35:

1. *The Example Applications were mapped to the Equipage Classes using engineering judgment as to their future potential range requirements.*

2. *Air-to-air ranges extending to 90 NM are intended to support the application of Delegated Separation in Oceanic/Low Density En Route Airspace, described as "Cooperative Separation" in RTCA DO-242A [27], §2.2.2.6. It is noted in RTCA DO-242A [27], §2.2.2.6, in connection with Table 2-4, that the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary.*

3. *As these applications are developed, these requirements may be further refined in terms of more stringent ranges and acquisition probability.*

4. *It is assumed that the population for which these acquisition requirements is to be met are aircraft that have been operating and broadcasting MS Reports within radio line of sight at ranges significantly greater than the acquisition range.*

5. *These values are based on the scenario in RTCA DO-242A [27], §2.2.2.5.2 which assumes a reduced horizontal separation standard of 2 NM. Separation standards of more than 2 NM may require longer acquisition ranges to provide adequate alerting times.*

3.4.3.4 ADS-B Network Capacity

ADS-B data links must be able to handle current and future air traffic density to insure that required performance is achieved. ADS-B link capacity is limited by co-channel interference in high traffic density environments. Co-channel interference is especially important in ADS-B links that share the channel with other systems, such as 1090 Extended Squitter. The 1090 MHz frequency is utilized by other systems including

TCAS, ATCRBS and Mode S SSRs, and multilateration systems that share the channel with 1090ES. Typically, this interference is primarily a function of the number of aircraft within 100 NM of the victim receiver as this relates to the typical Minimum Trigger Level (MTL) of the receiver. Targets beyond 100 NM are weaker and therefore are less of a contribution to interfering with desired signals. Another important factor for the 1090 MHz channel is the number of aircraft within 30 NM, as this is the range of highest TCAS activity. Since ADS-B receiver performance in this channel is also impacted by interfering signals produced by secondary surveillance radar, multilateration, and military identification-friend-foe interrogation replies, the number of these systems operating in a region must be considered.

The scenario representing the highest current traffic density, and the highest expected future ADS-B interference environment was derived from a review of ATC traffic level records as well as flight test data. The highest traffic density has been experienced in the Northeast Corridor so this air volume has been used as the basis for link capacity analysis and future traffic prediction. A baseline traffic scenario in the dense Northeast Corridor has been established from data collected during a July 2007 Northeast Corridor test flight. The traffic distribution was captured by taking ‘snapshots’ of all aircraft seen by as many as 33 En Route and terminal SSRs that provided coverage of the core area of interest. The composite picture was created by converting the measured SSR coordinates of all the aircraft at the time of the snapshot into latitude and longitude, superimposing the aircraft seen by all the SSRs, and eliminating duplicate reports of the same aircraft as seen by multiple SSRs.

Figure 3-14 shows the number of aircraft as a function of horizontal range from N39 (the test aircraft), the Newark airport (EWR) SSR site (which generally had the highest number of aircraft in view), and several other reference points. N39 was approximately 10 NM from EWR at the time of the snapshot. At this time, there were 10 aircraft within 6 NM of N39. A victim receiver over EWR would have had three aircraft within 6 NM at this time.

An approximate analytic fit to the data in the region around EWR is also shown on the plot. This general model, normalized to the test data, is given by:

$$No := 750 \qquad Ro := 200 \qquad \zeta := 0.2$$

$$nd := No \cdot \frac{\zeta + 1}{Ro^{(\zeta+1)}}$$

$$nd = 1.56 \qquad \rho(R) := nd \cdot R^{\zeta}$$

$$N(R) := \int_0^R \rho(R)\, dR$$

where No is the total traffic count within a range, Ro, and ζ is the empirically determined traffic distribution shape factor.

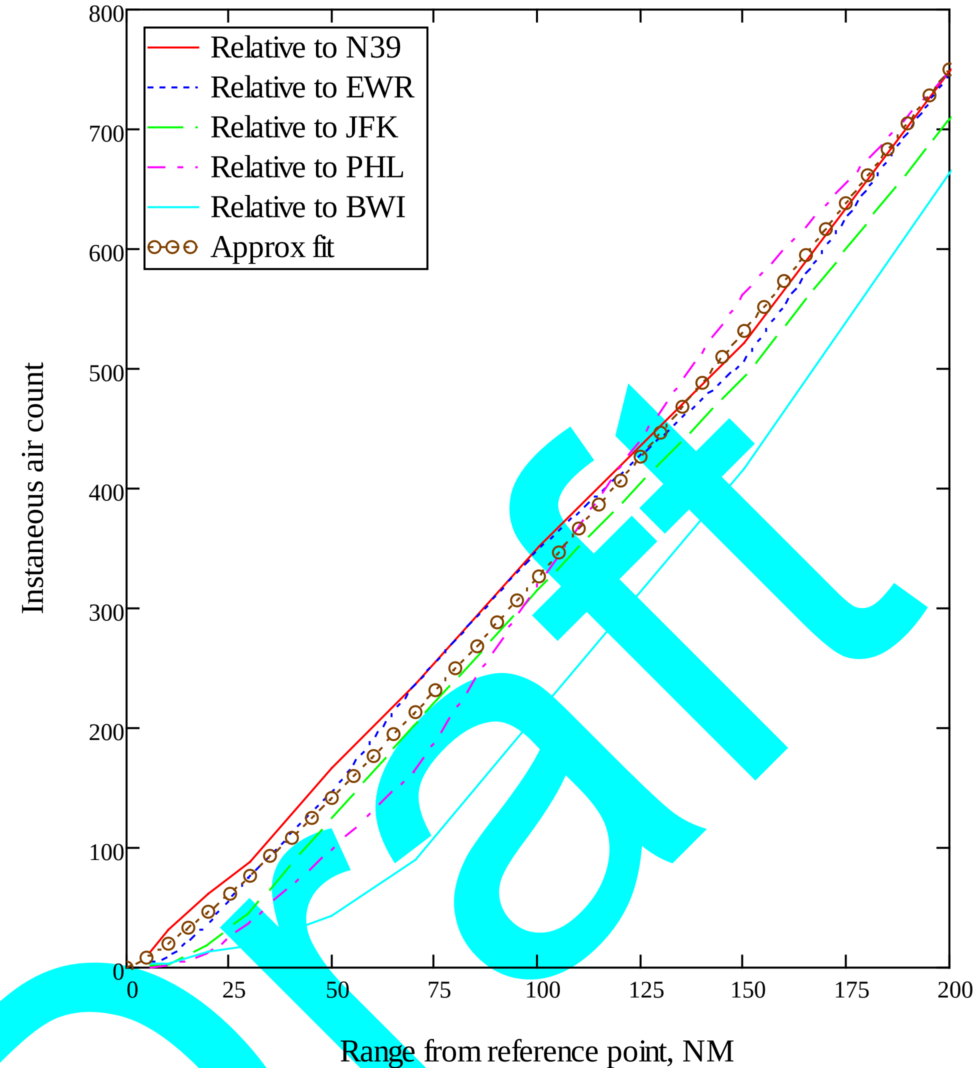


Figure 3-14: Radial traffic distributions during Northeast Corridor test flight

The traffic in view is also restricted by the line of sight range limit at lower altitudes or at ground sites. The fraction of traffic subjected to this limit depends on the altitude distribution of the traffic. An exponential altitude cumulative distribution model was initially fit to earlier New York regional collected data used as an input into Standard Terminal Automation Replacement System (STARS) processing load requirements determinations. The model is given by:

$$C := 0.09 \qquad p(h) := C e^{-C \cdot h}$$

$$F(H) := \int_0^H p(h)\, dh$$

This model is shown in Figure 3-15 to be in good agreement with measurements made during the 2007 test flight.

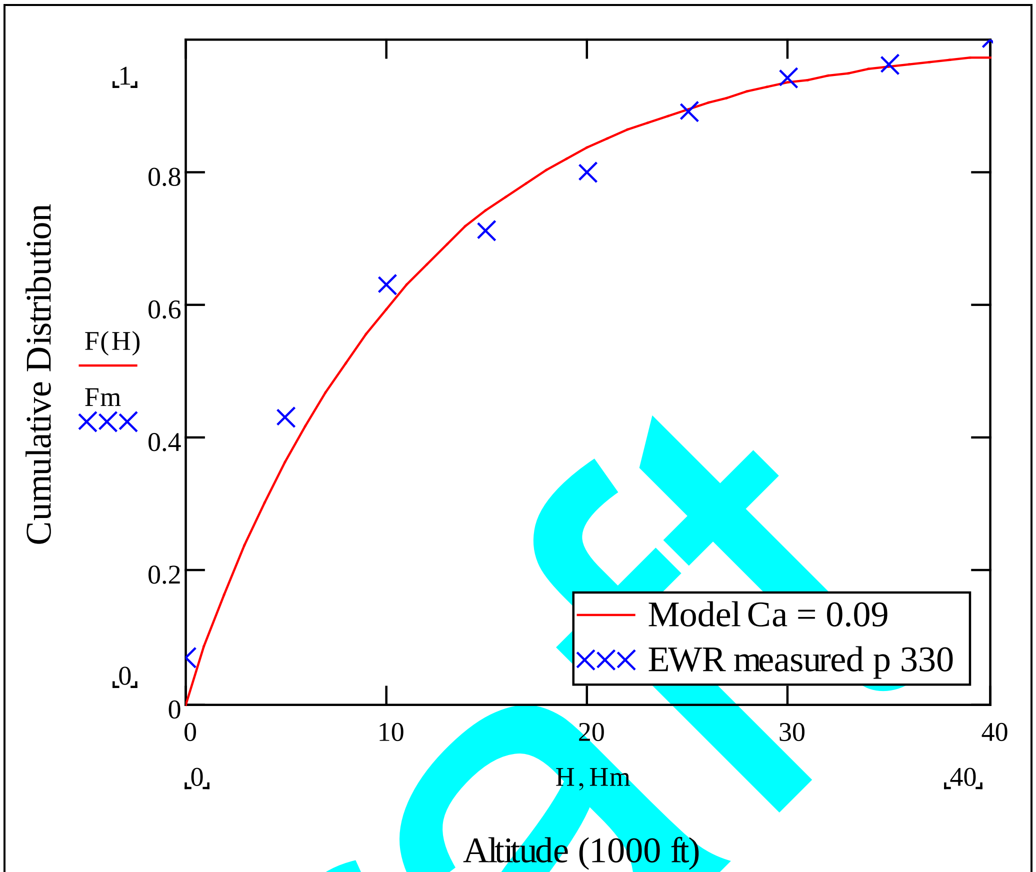


Figure 3-15: Cumulative Altitude Distribution Model vs. 25Jul07 Data

Future traffic levels in each region of the NAS are estimated by each ATC Traffic Control Center based on forecast growth rates of each airborne user class – commercial, general aviation, and military. These growth rates are sensitive to economic conditions as illustrated by a review of predicted growths over the last ten or so years. Recent growth rates forecast for the New York Center, ZNY, are compared in Figure 3-16 with historical high and low estimates.

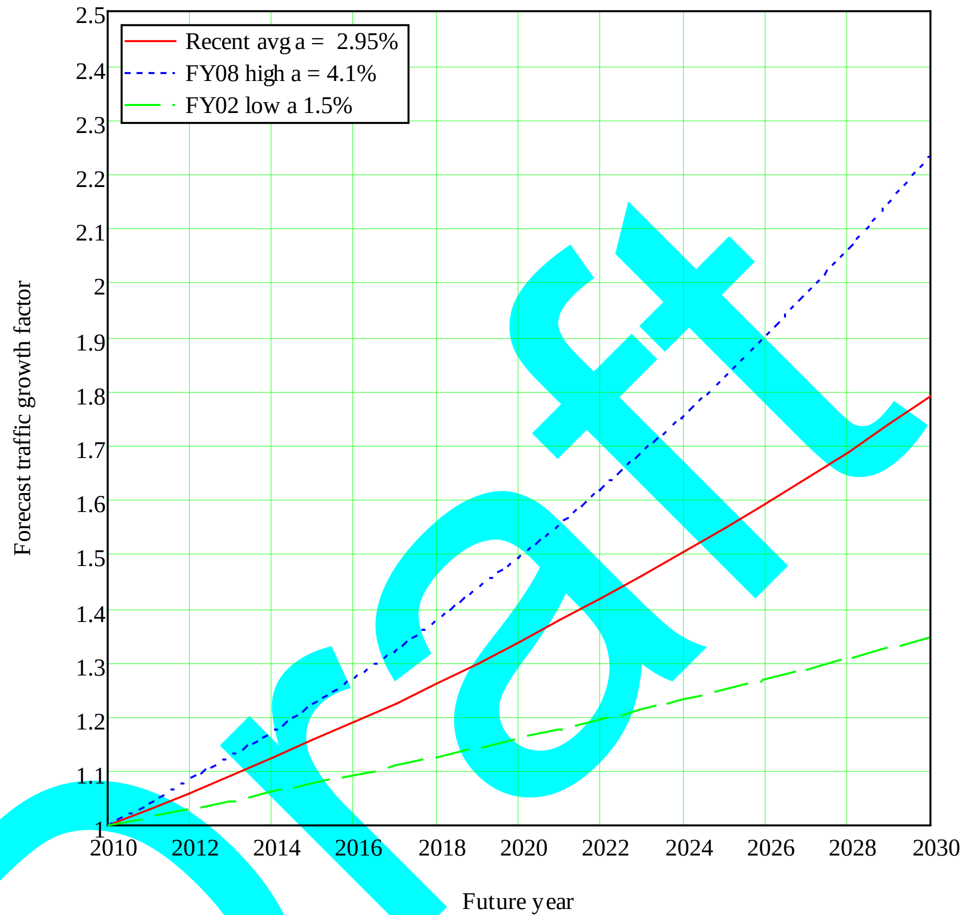
Future traffic models may be determined from these forecasts and the analytic fit to the current radial traffic distribution under the assumption that although the overall density will increase, the general horizontal and altitude distribution shapes will remain relatively unchanged. This just requires multiplication of the reference traffic count by the appropriate growth factor. Local adjustments to these results may be prudent for some applications of the model to assure nearby traffic densities are consistent with separation standards and ATC practices.

Interference estimates may also depend on the types of ADS-B users. Some change in this traffic mix is expected over the out years due to differences in user class growth rates. For example, while 82% of the current ZNY IFR handles are commercial aircraft, this is expected to increase to 84.5% in FY2025, and 85.1% in 2030. The general aviation fraction of the population will experience a slight decline from the current level of 12% to 11.3% in 2030. The military percentages over this period will drop from the current 6% to 3.6% in 2030.

Growth Factor $G_{NY}(m, a) := (1 + a)^{m}$ Future year $FY(m) := 2010 + m$

FY2011 ZNYY IFR forecast avg annual % growth, a = 2.8% for 2010-2030

FY2010 ZNY IFR forecast avg annual % growth, a = 3.1% for 2009-2030



Traffic growth factor for recent average ZNY forecast IFR growth rate with historical high and low forecast bounds

<u>Figure 3-16:</u> Recent ZNY traffic growth forecasts

3.4.3.5 ADS-B Medium

The ADS-B RF medium **shall (R3.220)** {from 242AR3.33} be suitable for all-weather operation, and ADS-B system performance will be specified relative to a defined interference environment for the medium. Radio frequencies used for ADS-B Message transmission **shall (R3.221)** {from 242AR3.34} operate in an internationally allocated aeronautical radionavigation band(s). Appendix E summarizes certain antenna and multipath considerations that relate to the selection of a frequency band and message format.

<u>Note:</u> *The interference environment for a particular ADS-B medium will be specified in the relevant MOPS.*

3.4.3.6 ADS-B System Quality of Service

3.4.3.6.1 Required Surveillance Performance

The term Required Surveillance Performance (RSP) refers to capabilities of an airspace user to surveil other users and be surveilled by other users and ATS at a level sufficient for participation of the user in both strategic and tactical operations. RSP is intended to characterize aircraft path prediction capability and received accuracy, integrity, continuity of service, and availability of a surveillance system for a given volume of airspace and/or phase of operation. Important surveillance system parameters such as state vector report received update rate can be derived from the primary RSP parameters.

Aircraft path prediction capability is defined by a 95 percent position uncertainty volume as a function of prediction time over a specified look ahead interval. Surveillance integrity (assurance of accurate, reliable information), where there is availability of service, must be defined consistent with the desired airspace application. Surveillance continuity of service and availability also must be defined consistent with the desired airspace application.

ADS-B delivery technologies, data definition, and applications must conform to appropriate RSP specifications on an end-to-end basis.

3.4.3.6.2 Failure Mode and Availability Considerations

Navigation and radar surveillance in the horizontal dimensions are independent; this independence is beneficial under certain failure modes. Today, an aircraft with failed navigation capability may get failure mode recovery vectors from ATS based on SSR/PSR tracks. Today, an aircraft with a failed transponder may still report navigation based position information to ATS for safe separation from other traffic even if no PSR is available. On the other hand, a navigation capability failure in an ADS-B only surveillance environment results in both the aircraft and ATS experiencing uncertainty about the aircraft's location. The operational impact of such a failure depends upon the nature of the failure: i.e., a single unit failure, or an area wide outage. Additional factors include the duration of the failure, the traffic density at the time of the failure, and the overall navigation and surveillance architecture. Detailed treatment of these issues should consider the failure mode recovery process in the context of the service outage duration and the total CNS environment. Figure 3-17 suggests how such a failure mode recovery process depends upon the total ATS architecture. Different states may implement different ATS architectures.

It is anticipated that ADS-B will be used as a supplemental means of surveillance for some ATS-based airspace operations during a transition period leading to full ADS-B equipage. When used as a supplemental means of surveillance, ADS-B adds availability within a larger surveillance system. Primary means of surveillance is defined as a preferred means (when other means are available) of obtaining surveillance data for aircraft separation and avoidance of obstacles. Use of ADS-B as a sole means of surveillance presumes that aircraft can engage in operations with no other means of surveillance. If ADS-B were to be used as a sole means of surveillance, availability would be calculated using only ADS-B, aircraft sources, and applications. ADS-B is not expected to be used as a sole means of ATS surveillance for the near future in US domestic airspace.

Where the ADS-B System is used as a supplemental means of surveillance, the ADS-B system is expected to be available with a probability of at least 0.95 for all operations, independent of the availability of appropriate inputs to the ADS-B system. Where the ADS-B System is used as a primary means of surveillance, the system is expected to be available with a probability of at least 0.999 for all air-air operations.

If an ADS-B system is used as a primary means of surveillance, then a supplemental surveillance system, independent of the navigation system, is expected to be available. The overall surveillance system will need to satisfy fail-safe operation of navigation and surveillance, i.e., a failure of the navigation system will not result in a failure of the surveillance function. This will enable ATS to provide an independent means of guidance to aircraft losing all navigation capability. The overall requirement for the surveillance system is adequate availability of the surveillance function, independent of navigation system availability. Where this requirement cannot be satisfied in a system intended for primary means of surveillance, the avionics and support infrastructure should be designed such that the simultaneous loss of both navigation and surveillance is extremely improbable. The expected availability of the total surveillance system is at least 0.99999, independent of navigation system availability.

3.4.3.6.3 ADS-B Availability Requirements

Availability is calculated as the ADS-B System Mean-Time-Between-Failures (MTBF) divided by the sum of the MTBF and Mean-Time-To-Restore (MTTR). ADS-B equipage is defined to be available for an operation if the ADS-B equipment outputs are provided at the rates defined in Table 3-34 and Table 3-35. For the purposes of calculating availability, an ADS-B transmission subsystem is considered to be one participant's message generation function and message exchange (transmission) function. An ADS-B receiver subsystem is considered to be one participant's message exchange (receiver) and one report generation function.

ADS-B availability **shall (R3.222)** {from 242AR3.35} be 0.9995 for class A0 through class A3 and class B0 through class B3 transmission subsystems. ADS-B availability **shall (R3.223)** {from 242AR3.36) be 0.95 for class A0 receiver subsystems. Class A1, A2, and A3 receiver subsystems **shall (R3.224)** {from 242AR3.37} have an availability of 0.9995. The ADS-R Service **shall (R3.225)** {new reqmt} have an availability of 0.99999. The TIS-B Service **shall (R3.226)** {new reqmt} have an availability of 0.999 Specification of Class C receiver subsystem availability requirements are beyond the scope of these MASPS.

High transmission availability (0.9995) is required of all classes in order to support the use of ADS-B as a primary means of surveillance for ATS. The combination of 0.9995 availability of transmission and 0.9995 availability of receive for classes A1 through A3 results in availability of 0.999, allowing the use of ADS-B as a primary means of surveillance for some air-to-air operations. A lower availability is permissible for Class A0 receiver subsystems as ADS-B is expected to be used as a supplemental, rather than as a primary tool of separation, for this class.

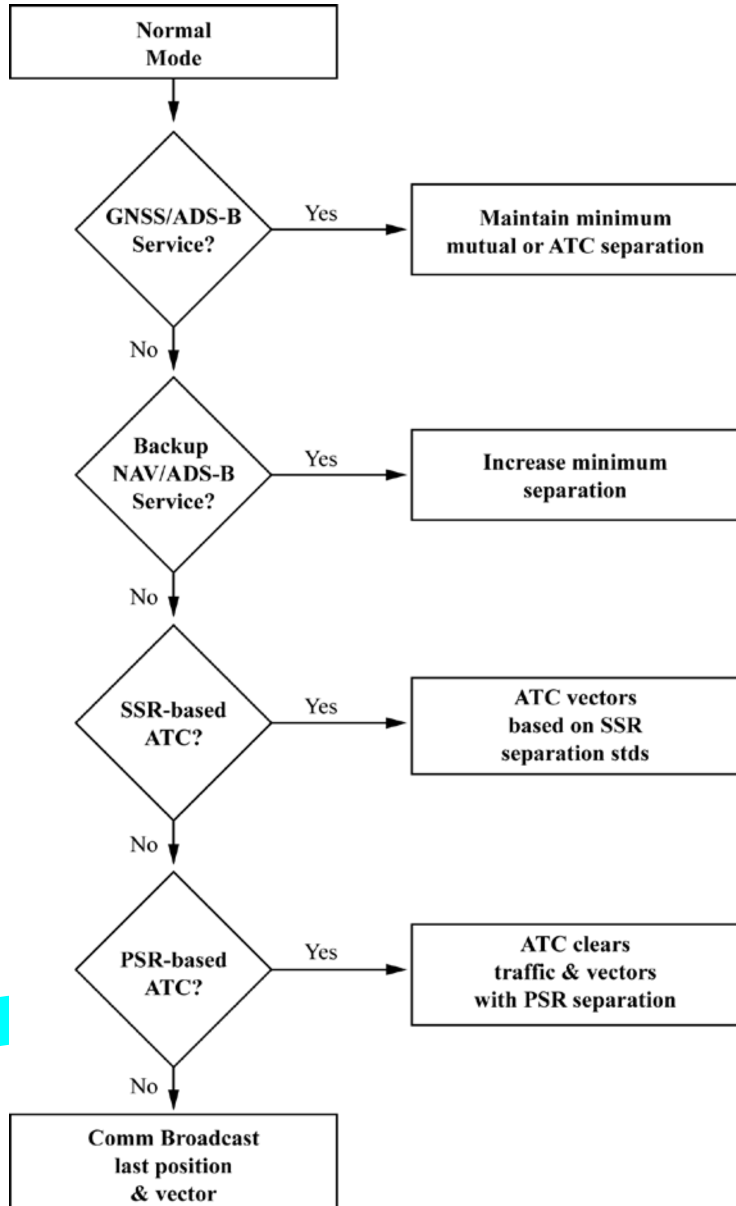


Figure 3-17: GNSS/ADS-B Surveillance/Navigation Failure Recovery Modes

3.4.3.6.4 ADS-B Continuity of Service

The probability that the ADS-B System, for a given ADS-B Message Generation Function and in-range ADS-B Report Generation Processing Function, is unavailable during an operation, presuming that the System was available at the start of that operation, **shall (R3.227)** {from 242AR3.38} be no more than 2 x 10^{-4} per hour of flight. The allocation of this requirement to ADS-B System Functions should take into account the use of redundant/diverse implementations and known or potential failure conditions such as equipment outages and prolonged interference in the ADS-B broadcast channel.

3.4.3.6.5 Subsystem Reliability

Each subsystem design should be capable of supporting ADS-B system Quality of Service (QOS). Specifications of each subsystem implementation will define requirements necessary to support the QOS. The subsystem should provide reliability required for the intended service environment commensurate with the criticality levels supported. Requirements for single thread or redundant configurations will depend on the FAR category of the operator, the aircraft system approval requirements, and the airspace operations supported by the subsystems.

MOPS or other subsystem specifications should provide definitive allocation of reliability factors considering failure probabilities, detected and undetected failure effects and probabilities specifically applicable to acquiring/transmitting and to receiving/reporting ADS-B exchanged information. Reliability includes maintenance of integrity in the applicable broadcast exchange technology. Attributes of the subsystem and the specific exchange technology must be shown to meet the operational and system requirements of Section §2.2 and Section §3.4 respectively. These requirements apply between all subsystems on a pair-wise basis. Assumptions pertaining to reliable exchange of data intended for use in separation support will be required to support certification and operational approval. All MOPS or other specifications governing implementations should define major design assumptions, system/subsystem allocations and means to validate the subsystem results.

3.4.3.7 ADS-B Receive Subsystem Functional Requirements

The ADS-B Receive Subsystem provides the receiving functionality for surveillance messages transmitted over each ADS-B data link, which includes ADS-B, ADS-R, and TIS-B Messages. It processes received messages and provides the corresponding ADS-B, ADS-R and TIS-B Reports to the ASSAP function. Users equipped with the UAT data link will also receive FIS-B messages; the TIS-B Service Status information is included in this service. Future implementations of the 1090ES data link may also convey TIS-B Service Status.

3.4.3.7.1 Message Reception

The ADS-B Receive Subsystem is expected to receive the appropriate link specific signal in space, detect and correct bit errors as appropriate, and conduct appropriate link specific monitoring functions. Additional requirements for the data link specific processing will be found in the ADS-B MOPS for each data link. {from 289-3.3.1.1}

The ADS-B Receive Subsystem **shall (R3.228)** {from 289R2.24, 289R3.165} receive link dependent messages from all ADS-B Transmit Subsystems within the application coverage volumes per Section §3.4.3.

The ADS-B Receive Subsystem **shall (R3.229)** {from 289R2.24, 289R3.165} receive link dependent messages from the ADS-R Transmit Subsystem within the corresponding Service Volume(s) where the ADS-R Service is being provided. {The service volumes where ADS-R is provided may or may not fully support all air-to-air applications as presented in section 3.2 of DO-289. We may need to reference corresponding section in these MASPS when available.}

The ADS-B Receive Subsystem **shall (R3.230)** {from 289R2.24, 289R3.165} receive link dependent messages from the TIS-B Transmit Subsystem within the corresponding Service Volume(s) where the TIS-B Service is being provided. {The service volumes where TIS-B is provided may or may not fully support all air-to-air applications as presented in section 3.2 of DO-289}

The ADS-B Receive Subsystem, for UAT data link users only, **shall (R3.231)** {new reqmt} receive FIS-B messages from the FIS-B transmit subsystem within the corresponding Service Volume(s) where the TIS-B Service is being provided to get TIS-B Service Status information.

3.4.3.7.2 Message Processing

The ADS-B Receive Subsystem **shall (R3.232)** {from 286R3.4-02} correlate, collate, decompress, re-partition, decode, or otherwise manipulate as necessary to reconstitute the ADS-B, ADS-R, TIS-B, and FIS-B Reports, as appropriate for each data link.

Note: *Additional requirements for the data link specific processing will be found in Section §3.5 of these MASPS and in the ADS-B MOPS for each data link.*

The ADS-B Receive Subsystem should not {from 289-2.4.3.3} track, extrapolate or otherwise manipulate received surveillance data, other than as necessary to assemble complete ADS-B, ADS-R and TIS-B Reports.

Note: *It is the responsibility of ASSAP to perform the traffic tracking function, including correlation, registration, smoothing, extrapolation, coasting.*

The ADS-B Receive Subsystem **shall (R3.233)** {from 289R3.166} assemble ADS-B, ADS-R and TIS-B reports containing State Data (see Table 3-29) and ID/Status (Table 3-29), and when required, application specific information for all received data.

The ADS-B Receive Subsystem **shall (R3.234)** {from 289R2.25, 289R3.167} update and pass all appropriate ADS-B, ADS-R, TIS-B or FIS-B reports to ASSAP each time any new (changed) information is received over the data link.

The ADS-B Receive Subsystem **shall (R3.235)** {new reqmt} indicate invalid or missing information (e.g., validity bit, or value of zero) for each required information element output to ASSAP.

The ADS-B Receive Subsystem **shall (R3.236)** {new reqmt} indicate in each report whether the information was derived from an ADS-B, TIS-B or ADS-R Message.

3.4.3.8 ADS-B Receive Subsystem Performance Requirements

3.4.3.8.1 Message Reception and Processing Rate

The ADS-B Receive Subsystem **shall (R3.237)** {new reqmt} successfully receive and process ADS-B, ADS-R, TIS-B, or FIS-B Messages to achieve the minimum report update interval and acquisition range for each equipment class presented in Table 3-34 and Table 3-35.

3.4.3.8.2 Processing Capacity

The ADS-B Receive Subsystem **shall (R3.238)** {from 289R2.26} be capable of processing the expected traffic within the coverage volume for each example application described in Table 3-34.

3.4.3.8.3 Receiver Reliability

The continuity risk and integrity risk requirements of Table 3-36 **shall (R3.239)** {from 289R3.168} be met by the ADS-B Receive Subsystem. {originally from Table 3-13 in DO-289}

<u>Table 3-36:</u> ADS-B Receive Subsystem Continuity Risk and Integrity Risk Requirements (Per flight hour)

Application	**EVAcq, AIRB, SURF** (less than 80 knots)	**EVAcq, AIRB, SURF** (greater than 80 knots)	**All Other Applications**
Subsystem Continuity Risk	10^{-3}	10^{-3}	TBD
Subsystem Integrity Risk	10^{-3}	10^{-5}	TBD

<u>Notes for Table 3-36:</u>

1. *Subsystem Integrity Risk is the probability, per flight hour, that a given subsystem will have an undetected failure and consequently, that the subsystem will provide misleading information.*
2. *Subsystem continuity risk is the probability per hour, that, given that the subsystem was operating at the start of the hour or operation, that the subsystem will fail to be available through the remainder of the hour or operation.*

3.4.3.8.4 Information Integrity

The probability that the ADS-B Receive Subsystem introduces an error into an ADS-B, ADS-R and TIS-B Messages that are received **shall (R3.240) not** {new reqmt} exceed 10^{-5} per message. {rate consistent with the FAA Critical Services Spec}

3.5 Messages and Reports

The ADS-B/TIS-B and ADS-R Receive Subsystem receives ADS-B, TIS-B and ADS-R Messages, processes them, and converts them into ADS-B/TIS-B/ADS-R reports for ASSAP.

3.5.1 ADS-B Messages and Reports

This section provides requirements and definitions of ADS-B Reports and the relationship between these reports and the received messages. The ADS-B output report definitions establish the standard contents and conditions for outputting data qualified for user applications. Exchange of broadcast messages and report assembly considerations are discussed in §3.5.1.2. Report data elements are specified in §3.5.1.3 to §3.5.1.8 and standardized according to content, nomenclature, parameter type, applicable coordinate system, logical content, and operational conditions. Reports required for each Equipment Class and supporting message contents are defined in §3.4.3.2. Report contents and message requirements are based on the information requirements summarized in Table 2-2. These definitions provide the basis for:

- Independence between applications and broadcast link technologies
- Interoperability of applications utilizing different ADS-B technologies.

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Specific digital formats are not defined since interface requirements will determine those details. Such interfaces may be internal processor buses or inter-system buses such as those described in ARINC, IEEE, and military standards. Additional information requirements may develop in the future and result in expansion to the report definitions specified in this document. ADS-B system designs should be sufficiently flexible to accommodate such future expansion.

3.5.1.1 Report Assembly Design Considerations

Four report types are defined as ADS-B outputs to applications. They provide flexibility in meeting delivery and performance requirements for the information needed to support the operations identified in Section 2. Report types are:

- Surveillance State Vector Report (SV, §3.5.1.3);
- Mode Status Report (MS, §3.5.1.4);
- Target State Report (TS, §3.5.1.7);
- Various On-Condition Reports (OC, §3.5.1.5) – a category that currently includes only the following report type:
  - Air Referenced Velocity Report (ARV, §3.5.1.6), and
  - Other On-Condition Reports, which may possibly be defined in future versions of these MASPS.

All interactive participants must receive messages and assemble reports specified for the respective equipage class (Table 3-32). All transmitting participants must output at least the minimum data for the SV and MS Reports. The minimum requirements for exchanged information and report contents applicable for equipage classes are provided in §3.4.3.2.

3.5.1.2 ADS-B Message Exchange Technology Considerations in Report Assembly

ADS-B participants can vary both in the information exchanged and in the applications supported. ADS-B Reports are assembled from received ADS-B Messages. Message formats are defined in MOPS or equivalent specifications for each link technology chosen for ADS-B implementation. Reports are independent of the particular message format and network protocol. In some ADS-B broadcast exchange technologies the information may be conveyed as a single message, while others may utilize multiple messages which require assembly in the receiving subsystem to generate the ADS-B Report. The report assembly function must be performed by the ADS-B subsystem prior to disseminating the report to the application.

Broadcast technologies vary in broadcast rate and probability of message reception. The receiving subsystem, therefore, must process messages compatibly with the message delivery performance to satisfy required performance as observed in the ADS-B Report outputs. Also, data compression techniques may be used to reduce the number of transmitted bits in message exchange designs.

The messages **shall (R3.241)** {from 242AR3.40} be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in §3.5.1.3 to §3.5.1.7. The message and report assembly processing capability of the receiving subsystem **shall (R3.242)** {from 242AR3.41} support the total population of the participants within detection range provided by the specific data link technology.

Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report **shall (R3.243)** {from 242AR3.42} be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant with the exception that no type of report is required to be issued at a rate of greater than once per second. The Report Assembler function converts the received messages into the reports appropriate to the information conveyed from the transmitting participant. The applicable reports **shall (R3.244)** {from 242AR3.43} be made available to the applications on a continual basis in accordance with the local system interface requirements.

Each ADS-B Report contains an address, for the purpose of enabling the receiver to associate the receptions into a single track. If the ADS-B design uses the ICAO 24-bit address, then there **shall (R3.245)** {from 242AR3.44} be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.

3.5.1.3 ADS-B State Vector Report

Table 3-37 lists the report elements that comprise the State Vector (SV) report. The SV Report contains information about an aircraft or vehicle's current kinematic state. Measures of the State Vector quality are contained in the NIC element of the SV Report and in the NAC_P, NAC_V, NIC_{BARO} and SIL elements of the Mode Status Report (§3.5.1.4).

Table 3-37: State Vector Report Definition

	SV Elem. #	Contents	[Resolution or # of bits]	Required from airborne participants	Required from surface participants	Reference Section	Notes
ID	1	Participant Address	[24 bits]	•	•	§3.2.2.2.1	
	2	Address Qualifier	[1 bit]	•	•	§3.2.2.2.2	1
TOA	3	Time Of Applicability	[0.2 s]	•	•	§3.5.1.3.3	
Geometric Position	4a	Latitude (WGS-84)		•	•	§3.5.1.3.4	2, 3
	4b	Longitude (WGS-84)		•	•		
	4c	Horizontal Position Valid	[1 bit]	•	•	§3.5.1.3.5	
	5a	Geometric Altitude		•		§3.5.1.3.6	3, 4
	5b	Geometric Altitude Valid	[1 bit]	•		§3.5.1.3.7	
Horizontal Velocity	6a	North Velocity while airborne		•		§3.5.1.3.8	3
	6b	East Velocity while airborne		•			3
	6c	Airborne Horizontal Velocity Valid	[1 bit]	•		§3.5.1.3.9	
	7a	Ground Speed while on the surface	[1 knot]		•	§3.5.1.3.10	
	7b	Surface Ground Speed Valid	[1 bit]		•	§3.5.1.3.11	
Heading	8a	Heading while on the Surface	[6° or better (6 bits)]		•	§3.5.1.3.12	
	8b	Heading Valid	[1 bit]		•	§3.5.1.3.13	
Baro Altitude	9a	Pressure Altitude		•		§3.5.1.3.14	3, 4
	9b	Pressure Altitude Valid	[1 bit]	•		§3.5.1.3.15	
Vertical Rate	10a	Vertical Rate (Baro/Geo)		•		§3.5.1.3.16	3
	10b	Vertical Rate Valid	[1 bit]	•		§3.5.1.3.17	
NIC	11	Navigation Integrity Category (NIC)	[4 bits]	•	•	§3.5.1.3.18	
Report Mode	12	SV Report Mode	[2 bits]	•		§3.5.1.3.19	

Notes for Table 3-37:

1. *The minimum number of bits required by these MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*
2. *A horizontal position resolution finer than 20 m will be required if the NAC_P element (§3.2.11) of the MS Report (§3.5.1.4) is 9 or greater.*
3. *Resolution requirements of these elements must be sufficient to meet the error requirements specified in Table 3-34.*
4. *Future revisions of these MASPS may not require that both geometric and pressure altitudes – if available – to be broadcast at the SV rate. Conditions will need to be specified as to when each altitude must be the "primary" altitude being sent at the SV rate.*

3.5.1.3.1 Air/Ground State

A transmitting ADS-B participant's air/ground state is an internal state in the ADS-B Transmitting Subsystem that affects which SV Report elements are to be broadcast, but which is not required to be broadcast in ADS-B Messages from that participant.

Notes:

1. *It is possible that a future edition of these MASPS would require a participant's air/ground state to be broadcast. This would occur if an operational concept for a user application that needs air/ground state were to be included in a future version of these MASPS.*

2. A transmitting ADS-B participant's air/ground state also affects whether the aircraft size (length and width) codes in the MS Report are to be broadcast (see §3.5.1.4.6).

A transmitting participant's air/ground state has the following possible values:

- "Known to be airborne,"
- "Known to be on the surface," and
- "Uncertain whether airborne or on the surface."

3.5.1.3.1.1 Determination of Air/Ground State

A transmitting ADS-B participant applies the following tests to determine its air/ground state:

1. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then it **shall (R3.246)** {from 242AR3.45} set its air/ground state to "known to be airborne:"

    a. Light Aircraft

    b. Glider or Sailplane

    c. Lighter Than Air

    d. Unmanned Aerial Vehicle

    e. Ultralight, Hang Glider, or Paraglider

    f. Parachutist or Skydiver

    g. Point Obstacle

    h. Cluster Obstacle

    i. Line Obstacle

    Note 1: *Because it is important for fixed ground or tethered obstacles to report altitude, Point Obstacles, Cluster Obstacles, and Line obstacles always report the "Airborne" state.*

2. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is one of the following, then that participant **shall (R3.247)** {from 242AR3.46} set its air/ground state to "known to be on the surface:"

    a. Surface Vehicle – Emergency

    b. Surface Vehicle – Service

3. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and that participant's emitter category is "rotorcraft," then that participant **shall (R3.248)** {from 242AR3.47} set its air/ground state to "uncertain whether airborne or on the surface."

   Note 2: *Because of the unique operating capability of rotorcraft (i.e., hover, etc.) an operational rotorcraft always reports the "uncertain" air/ground state, unless the "surface" state is specifically declared. This causes the rotorcraft to transmit those SV elements that are required from airborne ADS-B participants.*

4. If a transmitting ADS-B participant is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the surface, and its ADS-B emitter category is not one of those listed under tests 1, 2, and 3 above, then that participant's ground speed (GS), airspeed (AS) and radio height (RH) **shall (R3.249)** {from 242AR3.48-A} be examined, provided that some or all of those three parameters are available to the ADS-B Transmitting Subsystem. If GS < 100 knots, or AS < 100 knots, or RH < 50 feet, then the transmitting ADS-B participant **shall (R3.250)** {from 242AR3.48-B} set its Air/Ground state to "known to be on the surface."

5. If a transmitting ADS-B participant is equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is airborne, then that participant **shall (R3.251)** {from 242AR3.49} set its air/ground state to "known to be airborne."

6. If a transmitting ADS-B participant is equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, and that automatic means indicates that the participant is on the surface, then the following additional tests **shall (R3.252)** {from 242AR3.50} be performed to validate the "on-the-surface" condition:

   a. If the participant's ADS-B emitter category is any of the following:

      - "Small Aircraft" or
      - "Medium Aircraft" or
      - "High-Wake-Vortex Large Aircraft" or
      - "Heavy Aircraft" or
      - "Highly Maneuverable Aircraft" or
      - "Space or Trans-atmospheric Vehicle"

AND one or more of the following parameters is available to the transmitting ADS-B system:

- Ground Speed (GS) or
- Airspeed (AS) or
- Radio height from radio altimeter (RH)

AND any of the following conditions is true:

- GS > 100 knots or
- AS > 100 knots or
- RH > 100 50 ft,

THEN, the participant **shall (R3.253)** {from 242AR3.51-A} set its Air/Ground state to “known to be airborne.”

b. Otherwise, the participant **shall (R3.254)** {from 242AR3.51-B} set its Air/Ground state to “known to be on the surface.”

3.5.1.3.1.2 Effect of Air/Ground State

The set of SV elements to be broadcast by ADS-B participants is determined by those participants’ air/ground state as follows:

a. ADS-B participants that are known to be on the surface **shall (R3.255)** {from 242AR3.52} transmit those State Vector report elements that are indicated with bullets (“•”) in the “required from surface participants” column of Table 3-37.

b. ADS-B participants that are known to be airborne **shall (R3.256)** {from 242AR3.53} transmit those SV Report elements that are indicated by bullets (“•”) in the “required from airborne participants” column of Table 3-37.

c. ADS-B participants for which the air/ground state is uncertain **shall (R3.257)** {from 242AR3.54} transmit those SV Report elements that are indicated by bullets in the “required from airborne participants” column. It is recommended that such participants should also transmit those SV elements that are indicated with bullets in the “required from surface participants” column.

3.5.1.3.2 SV Report Update Requirements

Required SV Report update rates, described by operating range, are given in Table 3-34 (§3.4.3.3.1.1).

a. A receiving ADS-B subsystem **shall (R3.258)** {from 242AR3.55} update the SV Report that it provides to user applications about a transmitting ADS-B participant whenever it receives messages from that participant providing updated information about any of the SV Report elements with the exception that SV Reports are not required to be issued at a rate of greater than once per second.

b. For ADS-B systems that use segmented messages for SV data, time-critical SV Report elements that are not updated in the current received message **shall (R3.259)** {from 242AR3.56} be estimated whenever the SV Report is updated. The time-critical SV elements are defined as the following:

1. Geometric position (latitude, longitude, geometric height, and their validity flags – elements 4a, 4b, 4c, 5a, 5b);

2. Horizontal velocity and horizontal velocity validity (elements 6a, 6b, 6c, 7a, 7b);

3. Heading while on the surface (elements 8a, 8b);

4. Pressure altitude (elements 9a, 9b);

5. Vertical rate (elements 10a, 10b); and

6. NIC (element 11).

Note 1: *Estimation of NIC is done by simply retaining the last reported value.*

c. For time-critical elements of the SV Report, a ADS-B Receiving Subsystem's report assembly function **shall (R3.260)** {from 242AR3.57} indicate "no data available" if no data are received in the preceding coast interval specified in Table 3-34 (§3.4.3.3.1.1).

Note 2: *An ADS-B Receiving Subsystem may mark data elements as "no data available" by setting the associated validity bit(s) to ZERO. For NIC this is done by setting the value of NIC to ZERO.*

3.5.1.3.3 Time of Applicability (TOA) Field for SV Report

The Time of Applicability (TOA) field in the SV Report describes the time at which the elements of that report are valid.

Note: *As mentioned in the definition of latency in §3.3.1.1, the times of applicability of position and velocity may differ. The TOA field in the SV Report contains the time of applicability of position.*

The time of applicability (TOA) relative to local system time **shall (R3.261)** {from 242AR3.58} be updated with each State Vector report update.

Requirements on the accuracy of the TOA field in the SV Report may be paraphrased as follows:

a. The standard deviation of the SV Report time error is to be less than 0.5 second.

b. The mean report time error for the position elements of the SV Report is not to exceed 0.5 second.

c. The mean report time error for the velocity elements of the SV Report is not to exceed 1.5 seconds.

Note: *The recommended TOA resolution of 0.2 seconds specified in Table 3-37 will meet the specifications in items a, b, and c above.*

3.5.1.3.4 Horizontal Position

Horizontal position (§3.2.4) **shall (R3.262)** {from 242AR3.59} be reported as WGS-84 latitude and longitude. Horizontal position **shall (R3.263)** {from 242AR3.60} be reported with the full range of possible latitudes (-90° to +90°) and longitudes (-180° to +180°).

Horizontal position **shall (R3.264)** {from 242AR3.61} be communicated and reported with a resolution sufficiently fine so that it does not compromise the accuracy reported in the NAC_P field (§3.2.11) of the Mode Status Report (§3.5.1.4). Moreover, horizontal position **shall (R3.265)** {from 242AR3.62} be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal position error, σ_{hp}, listed in Table 3-34 20 m for airborne participants, or σ_{hp} = 2.5 m for surface participants.

3.5.1.3.5 Horizontal Position Valid Field

The Horizontal Position Valid field in the SV Report **shall (R3.266)** {from 242AR3.63-A} be set to ONE if a valid horizontal position is being provided in geometric position (latitude and longitude) fields of that report; otherwise, the Horizontal Position Valid field **shall (R3.267)** {from 242AR3.63-B} be ZERO.

3.5.1.3.6 Geometric Altitude Field

Geometric altitude **shall (R3.258)** {from 242AR3.64} be reported with a range from -1000 feet up to +100000 feet. If the NAC_P code (§3.2.11) reported in the MS Report (§3.5.1.4) is 9 or greater, the geometric altitude **shall (R3.269)** {from 242AR3.65} be communicated and reported with a resolution sufficiently fine that it does not compromise the vertical accuracy reported in the NAC_P field. Moreover, geometric altitude **shall (R3.270)** {from 242AR3.66} be communicated and reported with a resolution sufficiently fine so that it does not compromise the one-sigma maximum ADS-B contribution to vertical position error, σ_{vp}, listed in Table 3-34, σ_{vp} = 30 feet for airborne participants.

Note: *A resolution of 100 feet or finer is sufficient not to compromise the one-sigma (one standard deviation) ADS-B contribution to vertical position error listed in Table 3-34. This is because the error introduced by rounding altitude to the nearest multiple of 100 feet has a uniform probability distribution, for which the standard deviation is 100 feet divided by the square root of 12, that is, about 28.9 feet.*

3.5.1.3.7 Geometric Altitude Valid Field

The Geometric Altitude Valid field in the SV Report is a one-bit field which **shall (R3.271)** {from 242AR3.67} be ONE if valid data is being provided in the Geometric Altitude field (§3.5.1.3.6), or ZERO otherwise.

3.5.1.3.8 Geometric Horizontal Velocity

Geometric horizontal velocity is the horizontal component of the velocity of an A/V with respect to the earth (or with respect to an earth-fixed reference system, such as the WGS-84 ellipsoid). The range of reported horizontal velocity **shall (R3.272)** {from 242AR3.68] accommodate speeds of up to 250 knots for surface participants and up to 4000 knots for airborne participants. Horizontal velocity **shall (R3.273)** {from 242AR3.69} be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode Status report. Moreover, horizontal velocity **shall (R3.274)** {from 242AR3.70} be communicated and reported with a resolution sufficiently fine so that it does not compromise the one-sigma maximum ADS-B contribution to horizontal velocity error, σ_{hv}, listed in Table 3-34, that is, 0.5 m/s (about 1 knot) for airborne participants with speeds of 600 knots or less, or 0.25 m/s (about 0.5 knot) for surface participants.

Note: *The rounding of velocity to the nearest encoded representation may be modeled with a uniform probability distribution. As such, the standard deviation (one-sigma velocity error, σ_{hv}) due to rounding to the nearest possible encoded representation is the weight of the LSB divided by the square root of 12. Thus, σ_{hv} = 0.5 m/s (about 1 knot) for airborne participants implies a resolution of $res_{hv} = \sigma_{hv} \cdot \sqrt{12}$ = 1.73 m/s (about 3.4 knots), so even a horizontal velocity resolution of 2 knots is sufficiently fine to meet the constraint imposed by Table 3-34 on airborne participants with speeds up to 600 knots. Likewise, a horizontal velocity resolution of 1 knot is sufficiently fine to satisfy the constraint imposed by Table 3-34 for surface participants.*

3.5.1.3.9 Airborne Horizontal Velocity Valid Field

The Airborne Horizontal Velocity Valid field in the SV Report is a one-bit field which **shall (R3.275)** {from 242AR3.71-A} be set to ONE if a valid horizontal geometric velocity is being provided in the “North Velocity while airborne” and “East Velocity while airborne” fields of the SV Report. Otherwise, the “Airborne Horizontal Velocity Valid” field **shall (R3.276)** {from 242AR3.71-B} be set to ZERO.

3.5.1.3.10 Ground Speed While on the Surface Field

The ground speed (the magnitude of the geometric horizontal velocity) of an A/V that is known to be on the surface **shall (R3.277)** {from 242AR3.72} be reported in the “ground speed while on the surface” field of the SV Report. For A/Vs moving at ground speeds less than 70 knots, the ground speed **shall (R3.278)** {from 242AR3.73} be communicated and reported with a resolution of 1 knot or finer. Moreover, the resolution with which the “ground speed while on the surface” field is communicated and reported **shall (R3.279)** {from 242AR3.74} be sufficiently fine so as not to compromise the accuracy of that speed as communicated in the NAC_V field of the MS Report (§3.5.1.4).

3.5.1.3.11 Surface Ground Speed Valid Field

The Surface Ground Speed Valid field in the SV Report is a one-bit field which **shall (R3.280)** {from 242AR3.75} be ONE if valid data is available in the Ground Speed While on the Surface field (§3.5.1.3.10), or ZERO otherwise.

3.5.1.3.12 Heading While on the Surface Field

Heading (§3.2.7) indicates the orientation of an A/V, that is, the direction in which the nose of an aircraft is pointing. ADS-B Participants are not required to broadcast heading if their Length/Width code (part of the aircraft size code, Table 3-3) is ZERO (0). However, each ADS-B participant that reports a length code of 2 or greater **shall (R3.281)** {from 242AR3.76} transmit messages to support the Heading element of the SV Report when that participant is on the surface and has a source of Heading available to its ADS-B Transmitting Subsystem.

Heading **shall (R3.282)** {from 242AR3.77-A} be reported for the full range of possible headings (the full circle, from 0° to nearly 360°). The heading of surface participants **shall (R3.283)** {from 242AR3.77-B} be communicated and reported with a resolution of 6 degrees of arc or finer.

<u>Notes:</u>

1. *If heading is encoded as a binary fraction of a circle, a resolution of 6° of arc or finer would require at least 6 binary bits.*

2. *The reference direction for heading (true north or magnetic north) is communicated in the True/Magnetic Heading Flag (§3.2.7) of the MS Report.*

3. *For operations at some airports, heading may be required to enable proper orientation and depiction of an A/V by applications supporting those surface operations.*

3.5.1.3.13 Heading Valid Field

The "Heading Valid" field in the SV Report **shall (R3.284)** {from 242AR3.78-A} be ONE if a valid Heading is provided in the "Heading While on the Surface" field of the SV Report; otherwise, it **shall (R3.285)** {from 242AR3.78-B} be ZERO.

3.5.1.3.14 Pressure Altitude Field

Barometric pressure altitude **shall (R3.286)** {from 242AR3.79} be reported referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in Hg). Barometric pressure altitude **shall (R3.287)** {from 242AR3.80} be reported over the range of -1000 feet to +100000 feet.

If a pressure altitude source with 25 foot or better resolution is available to the ADS-B Transmitting Subsystem, then pressure altitude from that source **shall (R3.288)** {from 242AR3.81-A} be communicated and reported with 25 foot or finer resolution. Otherwise, if a pressure altitude source with 100 foot or better resolution is available, pressure altitude from that source **shall (R3.289)** {from 242AR3.81-B} be communicated and reported with 100 foot or finer resolution.

3.5.1.3.15 Pressure Altitude Valid Field

The "pressure altitude valid" field in the SV Report is a one-bit field which **shall (R3.290)** {from 242AR3.82-A} be ONE if valid information is provided in the "pressure altitude" field. Otherwise, the "pressure altitude valid" field **shall (R3.291)** {from 242AR3.82-B) be ZERO.

3.5.1.3.16 Vertical Rate Field

The “vertical rate” field in the SV Report contains the altitude rate of an airborne ADS-B participant. This **shall (R3.292)** {from 242AR3.83} be either the rate of change of pressure altitude or of geometric altitude, as specified by the “vertical rate type” element in the MS Report. The range of reported vertical rate **shall (R3.293)** {from 242AR3.84} accommodate up to ±32000 ft/min for airborne participants. Geometric vertical rate **shall (R3.294)** {from 242AR3.85} be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode Status report. Moreover, vertical rate **shall (R3.295)** {from 242AR3.86} be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical rate error, σ_{vv}, listed in Table 3-34, that is, 1.0 ft/s for airborne participants.

3.5.1.3.17 Vertical Rate Valid Field

The “Vertical Rate Valid” field in the SV Report is a one-bit field which **shall (R3.296)** {from 242AR3.87-A} be ONE if valid information is provided in the “Vertical Rate” field. Otherwise, the “Vertical Rate Valid” field **shall (R3.297)** {from 242AR3.87-B} be ZERO.

3.5.1.3.18 Navigation Integrity Category (NIC) Field

The NIC field in the SV Report is a 4-bit field that **shall (R3.298)** {from 242AR3.88} report the Navigation Integrity Category (§3.2.10) encoded as described in Table 3-7.

3.5.1.3.19 Report Mode Field

The “Report Mode” provides a positive indication when SV and MS acquisition is complete and all applicable data sets and modal capabilities have been determined for the participant or that a default condition is determined by the Report Assembly function. The information for this SV element is not transmitted over the ADS-B data link, but is provided by the report assembly function at the receiving ADS-B participant. Table 3-38 lists the possible values for the SV Report Mode.

Table 3-38: SV Report Mode Values.

Value	Meaning
0	Acquisition
1	Track
2	Default

3.5.1.4 Mode Status Report

The mode-status (MS) report contains current operational information about the transmitting participant. This information includes participant type, mode specific parameters, status data needed for certain pair-wise operations, and assessments of the integrity and accuracy of position and velocity elements of the SV Report. Specific requirements for a participant to supply data for and/or generate this report subgroup will vary according to the equipage class of each participant. §3.4.3.2 defines the required capabilities for each Equipage Class defined in §3.1.1.3. Equipage classes define the level of MS information to be exchanged from the source participant to support correct classification onboard the user system.

The Mode Status report for each acquired participant contains the unique participant address for correlation purposes, static and operational mode information and Time of Applicability. Contents of the Mode Status report are summarized in Table 3-39.

The static and operational mode data includes the following information:

- Capability Class (CC) Codes – used to indicate the capabilities of a transmitting ADS-B participant.
- Operational Mode (OM) Codes – used to indicate the current operating mode of a transmitting ADS-B participant.

For each participant the Mode-status report **shall (R3.299)** {from 242AR3.89} be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant.

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Table 3-39: Mode Status (MS) Report Definition.

	MS Elem. #	Contents	[Resolution or # of bits]	Elements That Require Rapid Update	Reference Section	Notes
ID	1	Participant Address	[24 bits]		§3.2.2.2.1	
	2	Address Qualifier	[1 bit]		§3.2.2.2.2	1
TOA	3	Time of Applicability	[1 s resolution]		§3.5.1.4.2	
Version	4	ADS-B Version Number	[3 bits]		§3.5.1.4.3	
ID, Continued	5a	Call Sign	[up to 8 alpha-numeric characters]		§3.5.1.4.4	
	5b	Emitter Category	[5 bits]		§3.5.1.4.5	
	5c	A/V Length and Width Codes	[4 bits]		§3.5.1.4.6	2
Status	6a	Mode Status Data Available	[1 bit]		§3.5.1.4.7	
	6b	Emergency/Priority Status	[3 bits]		§3.5.1.4.8	3
CC, Capability Codes	7	7a: TCAS/ACAS operational	[1 bit]	•	§3.5.1.4.9	4
		7b: 1090 MHz ES Receive Capability	[1 bit]		§3.5.1.4.9	
		7c: ARV Report Capability Flag	[1 bit]		§3.5.1.4.9	
		7d: TS Report Capability Flag	[1 bit]		§3.5.1.4.9	
		7e: TC Report Capability Level	[2 bits]		§3.5.1.4.9	
		7f: UAT Receive Capability	[1 bit]		§3.5.1.4.9	
		(CC Codes reserved for future growth)	[3 bits]		§3.5.1.4.9	
OM, Operational Mode	8	8a: TCAS/ACAS resolution advisory active	[1 bit]	•	§3.5.1.4.10	4
		8b: IDENT Switch Active	[1 bit]		§3.5.1.4.10	3
		8c: Reserved for Receiving ATC services	[1 bit]		§3.5.1.4.10	
		(Reserved for future growth)	[2 bits]		§3.5.1.4.10	
SV Quality	9a	Nav. Acc. Category for Position (NAC_P)	[4 bits]	•	§3.5.1.4.11	4
	9b	Nav. Acc. Category for Velocity (NAC_V)	[3 bits]	•	§3.5.1.4.12	4
	9c	Source Integrity Level (SIL)	[2 bits]	•	§3.5.1.4.13	4
	9d	NIC_{BARO} - Altitude Cross Checking Flag	[1 bit]		§3.5.1.4.14	
	9e	Geometric Vertical Accuracy (GVA)	[2 bits]		§3.5.1.4.15	
	9f	System Design Assurance (SDA)	[2 bits]		§3.5.1.4.16	
	9g	SIL Supplement	[1 bit]		§3.5.1.4.22	
	9h	(Reserved for future growth)	[2 bits]		§3.5.1.4.17	
Data Reference	10a	True/Magnetic Heading	[1 bit]		§3.5.1.4.18	
	10b	Vertical Rate Type (Baro./Geo.)	[1 bit]		§3.5.1.4.19	
	10c	Single Antenna Flag (SAF)	[1 bit]		§3.5.1.4.20	
	10d	GPS Antenna Offset	[8 bits]		§3.5.1.4.21	
Other	11	Reserved for Flight Mode Specific Data	[3 bits]		§3.5.1.4.23	

Notes for Table 3-39:

1. *The minimum number of bits required by these MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. For example, address qualifier bits might be needed to distinguish reports about TIS-B targets from reports about ADS-B targets. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*

2. *The aircraft size code only has to be transmitted by aircraft above a certain size, and only while those aircraft are on the ground. (See §3.5.1.4.6 for details.)*

3. These elements are primarily for air-to-ground use. Update rate requirements for ground applications are not defined in these MASPS. If higher rates are later deemed to be required, they will be addressed in a future revision of these MASPS.

4. Changes to the values of these elements may trigger the transmission of messages conveying the changed values at higher than nominal update rates. (Only those elements whose values have changed need be updated, not the entire MS Report.) These update rates, the duration for which those rates must be maintained, and the operational scenario to be used to evaluate these requirements are to be defined in a future revision of these MASPS.

3.5.1.4.1 MS Report Update Requirements

The report assembly function **shall (R3.300)** {from 242AR3.90-A} provide updates when received. For those elements indicated in Table 3-39 as "elements that require rapid update", the report assembly function **shall (R3.301)** {from 242AR3.90-B} indicate the data has not been refreshed with the "Mode Status Data Available" bit (§3.5.1.4.7) if no update is received in the preceding 24 second period.

Note: *The 24-second period before which the "Mode Status Data Available" bit is cleared was chosen as being the longest coast interval for SV Reports, as indicated in Table 3-34.*

3.5.1.4.2 Time of Applicability (TOA) Field for MS Report

The time of applicability relative to local system time **shall (R3.302)** {from 242AR3.91} be updated with every Mode Status report update.

3.5.1.4.3 ADS-B Version Number

The ADS-B Version Number conveyed in the MS Report specifies the ADS-B version of the ADS-B transmitting system as specified in Table 3-13.

Note: *Messages transmitted to support this report element might signify lower level document (i.e., MOPS) version. However, ADS-B Reports need to – at a minimum – signify the MASPS version so that applications can appropriately interpret received ADS-B data.*

3.5.1.4.4 Call Sign Field

An ADS-B participant's call sign (§3.2.2.1) is conveyed in the Call Sign field of the MS Report. The call sign **shall (R3.303)** {from 242AR3.93} consist of up to 8 alphanumeric characters. The characters of the call sign **shall (R3.304)** {from 242AR3.94} consist only of the capital letters A-Z, the decimal digits 0-9, and – as trailing pad characters only – the "space" character.

3.5.1.4.5 Emitter Category Field

An ADS-B participant's Emitter Category code (§3.2.2.3) is conveyed in the Emitter Category field of the MS Report. The particular encoding of the Emitter Category is not specified in these MASPS, being left for lower level specification documents, such as the MOPS for a particular ADS-B data link. Provision in the encoding **shall (R3.305)** {from

242AR3.95} be made for at least 24 distinct emitter categories, including the particular categories listed in §3.2.2.3.

3.5.1.4.6 A/V Length and Width Codes

The "A/V Length and Width Codes" field in the MS Report is a 4-bit field that describes the amount of space that an aircraft or ground vehicle occupies. The aircraft/vehicle length and width codes **shall (R3.306)** {from 242AR3.96} be encoded as described in Table 3-3. The aircraft size code is a four-bit code, in which the 3 most significant bits (the length code) classify the aircraft into one of eight length categories, and the least significant bit (the width code) classifies the aircraft into a "narrow" or "wide" subcategory.

Each aircraft **shall (R3.307)** {from 242AR3.97} be assigned the smallest length and width codes for which its overall length and wingspan qualify it.

Note: *For example, consider a powered glider with overall length of 24 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 1. But since the wingspan exceeds 34 m, it will not fit within even the "wide" subcategory of length category 1. Such an aircraft would be assigned length category 4 and width category 1, meaning "length less than 55 m and wingspan less than 52 m."*

Each aircraft ADS-B participant for which the length code is 2 or more (length greater than or equal to 25 m or wingspan greater than 34 m) **shall (R3.308)** {from 242AR3.98} transmit its aircraft size code while it is known to be on the surface. For this purpose, the determination of when an aircraft is on the surface **shall (R3.309)** {from 242AR3.99} be as described in §3.5.1.3.1.1.

3.5.1.4.7 Mode Status Data Available Field

The Mode Status Data Available field is a one-bit field in the MS Report. The report assembly function **shall (R3.310)** {from 242AR3.100-A} set this field to ZERO if no data has been received within 24 seconds under the conditions specified in §3.5.1.4.1. Otherwise, the report assembly function **shall (R3.311)** {from 242AR3.100-B} set this bit to ONE.

3.5.1.4.8 Emergency/Priority Field

The emergency/priority status field in the MS Report is a 3-bit field which **shall (R3.312)** {from 242AR3.101} be encoded as indicated in Table 3-11.

3.5.1.4.9 Capability Class (CC) Code Fields

Capability Class (CC) codes are used to indicate the capability of a participant to support engagement in various operations. Known specific capability class codes that are included in the MS Report are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available class codes, including appropriate combinations thereof.

<u>Airborne Capability Class Codes</u>

- TCAS/ACAS operational (§3.2.8.1)
- 1090ES IN & UAT IN (§3.2.8.2 and §3.2.8.6)
- ARV report capability (§3.2.8.3)
- TS Report capability (§3.2.8.4)
- TC report capability level (§3.2.8.5)
- Other capabilities, to be defined in later versions of these MASPS

<u>Surface Capability Class Codes</u>

- 1090ES IN & UAT IN (§3.2.8.2 and §3.2.8.6)
- NAC_V (§3.2.12)
- Other capabilities, to be defined in later versions of these MASPS

3.5.1.4.10 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational mode of transmitting ADS-B participants. Specific operational mode codes included in the MS Report are listed below. Unless noted, these parameters **shall (R3.313)** {new reqmt} be broadcast in both airborne and surface operational status messages. However, this is not an exhaustive set and provision should be made for future expansion of available OM codes, including appropriate combinations thereof.

- TCAS/ACAS resolution advisory active (§3.2.9.1).
- IDENT switch active flag (§3.2.9.2)
- Reserved for Receiving ATC services (§3.2.9.3)
- Other operational modes, to be defined in later versions of these MASPS.

3.5.1.4.11 Navigation Accuracy Category for Position (NAC_P) Field

The Navigation Accuracy Category for Position (NAC_P, §3.2.11) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use. The NAC_P field in the MS Report is a 4-bit field which **shall (R3.314)** {from 242AR3.113} be encoded as described in Table 3-8 in §3.2.11.

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.5.1.4.12 Navigation Accuracy Category for Velocity (NAC_V) Field

The Navigation Accuracy Category for Velocity (NAC_V, §3.2.12) is reported so that surveillance applications may determine whether the reported velocity has an acceptable level of accuracy for the intended use. The NAC_V field in the MS Report is a 3-bit field which **shall (R3.315)** {from 242AR3.114} be encoded as described in Table 3-9 (§3.2.12).

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.5.1.4.13 Source Integrity Level (SIL) Field

The SIL field in the MS Report is a 2-bit field which defines the probability of the reported horizontal position exceeding the containment radius defined by the NIC (§3.2.10), without alerting, assuming no avionics faults. The SIL field **shall (R3.316)** {from 242AR3.115} be coded as described in Table 3-10 (§3.2.13).

Note: *A change in the value of this field will trigger the transmission of messages conveying the updated value. These messages will be consistent with higher report update rates to be specified in a future version of these MASPS. The duration for which the higher report update requirements are to be maintained will also be defined in a future version of these MASPS.*

3.5.1.4.14 NIC_{BARO} Field

The NIC_{BARO} field in the MS Report is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude. A transmitting ADS-B participant **shall (R3.317)** {from 242AR3.117-A} set NIC_{BARO} to ONE in the messages that it sends to support the MS Report only if there is more than one source of barometric pressure altitude data and cross-checking of one altitude source against the other is performed so as to clear the "barometric altitude valid" flag in the SV Report if the two altitude sources do not agree. Otherwise, it **shall (R3.318)** {from 242AR3.117-B} set this flag to ZERO.

3.5.1.4.15 Geometric Vertical Accuracy (GVA)

The Geometric Vertical Accuracy (GVA) parameter is a 2-bit field in the MS Report, which is the representation of the 95% accuracy estimate of the geometric altitude (HAE) as output by the GNSS position source. The GVA parameter **shall (R3.319)** {new reqmt} be encoded as defined in §3.2.16. In some GNSS position sources this output parameter is known as the Vertical Figure of Merit (VFOM).

3.5.1.4.16 System Design Assurance (SDA)

The System Design Assurance (SDA) parameter in the MS Report is a 2-bit field that defines the failure condition that the position transmission chain is designed to support. The position transmission chain includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data and position quality metrics that will be transmitted. The SDA parameter **shall (R3.320)** {new reqmt} be encoded as defined in §3.2.32.

3.5.1.4.17 Reserved for MS Report

A 2-bit field in the MS Report **shall (R3.321)** {from 242AR3.116} be reserved for future use.

3.5.1.4.18 True/Magnetic Heading Flag

The True/Magnetic Heading Flag in the MS Report is a one-bit field which **shall (R3.322)** {from 242AR3.118} be ZERO to indicate that heading is reported referenced to true north, or ONE to indicate that heading is reported referenced to magnetic north.

Note: *The True/Magnetic Heading Flag applies to the Heading being reported in the SV Report while on the surface (§3.5.1.3.12), Heading reported in the ARV Report while airborne (§3.5.1.6.6), and the Selected Target Heading reported in the TS Report (§3.5.1.7.7).*

3.5.1.4.19 Vertical Rate Type Field

The Primary Vertical Rate Type field in the MS Report is a one-bit flag which **shall (R3.323)** {from 242AR3.119} be ZERO to indicate that the vertical rate field in the SV Report §3.5.1.3.16 holds the rate of change of barometric pressure altitude, or ONE to indicate that the vertical rate field holds the rate of change of geometric altitude.

3.5.1.4.20 Single Antenna Flag (SAF)

The Single Antenna Flag (SAF) in the MS Report is a one-bit field that is used to indicate that the ADS-B Transmitting Subsystem is operating with a single antenna. The Single Antenna Flag **shall (R3.324)** {from 242AR3.112-B} be encoded as defined in §3.2.31.

3.5.1.4.21 GPS Antenna Offset

The GPS Antenna Offset field in the MS Report is an 8-bit field in the ADS-B surface type messages that defines the position of the GPS antenna encoded as the longitudinal distance from the NOSE of the aircraft, and the lateral distance from the longitudinal axis (Roll) of the aircraft. The GPS Antenna Offset field **shall (R3.325)** {new reqmt} be encoded as defined in §3.2.33.

3.5.1.4.22 SIL Supplement

The “SIL Supplement” (Source Integrity Level Supplement) subfield in the MS Report is a 1-bit field that **shall (R3.326)** {new reqmt} define whether the reported SIL probability is based on a “per hour” probability or a “per sample” probability as defined in Table 3-40.

Table 3-40: “SIL Supplement” Subfield Encoding

Coding	Meaning
0	Probability of exceeding NIC radius of containment is based on “per hour”
1	Probability of exceeding NIC radius of containment is based on “per sample”

- **Per Hour:** The probability of the reported geometric position laying outside the NIC containment radius in any given hour without an alert or an alert longer than the allowable time-to-alert.

  Note: *The probability of exceeding the integrity radius of containment for GNSS position sources are based on a per hour basis, as the NIC will be derived from the GNSS Horizontal Protection Level (HPL) which is based on a probability of* 1×10^{-7} *per hour.*

- **Per Sample:** The probability of a reported geometric position laying outside the NIC containment radius for any given sample.

  Note: *The probability of exceeding the integrity radius of containment for IRU, DME/DME and DME/DME/LOC position sources may be based on a per sample basis.*

3.5.1.4.23 (Reserved for) Flight Mode Specific Data Field

A 3-bit field in the MS Report is reserved for future use as a “Flight Mode Specific Data” field. In the current version of these MASPS, the “Reserved for Flight Mode Specific Data” field **shall (R3.327)** {from 242AR3.120} be ZERO.

3.5.1.5 On-Condition Reports

The following paragraph (§3.5.1.6) describes an On Condition (OC) Report. The OC Report is a report for which messages are not transmitted all the time, but only when certain conditions are satisfied. There is currently only one OC Report defined:

ARV: Air Referenced Velocity (ARV) Report (§3.5.1.6).

Other On-Condition Reports may be defined in future versions of these MASPS.

3.5.1.6 Air Referenced Velocity (ARV) Report

The Air Referenced Velocity (ARV) report contains velocity information that is not required from all airborne ADS-B transmitting participants, and that may not be required at the same update rate as the position and velocity elements in the SV Report. Table 3-41 lists the elements of the ARV Report.

Table 3-41: Air Referenced Velocity (ARV) Report Definition

	ARV Elem. #	Contents [Resolution or # of bits]	Reference Section	Notes
ID	1	Participant Address [24 bits]	§3.2.2.2.1	
	2	Address Qualifier [1 bit]	§3.2.2.2.2	1
TOA	3	Time of Applicability [1 s resolution]	§3.5.1.6.3	
Airspeed	4a	Airspeed [1 knot or 4 knots]	§3.5.1.6.4	
	4b	Airspeed Type and Validity [2 bits]	§3.5.1.6.5	
Heading	5a	Heading while airborne [1 degree]	§3.5.1.6.6	2
	5b	Heading Valid [1 bit]	§3.5.1.6.7	

Notes for Table 3-41:

1. *The minimum number of bits required by these MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits allocated for the Address Qualifier field may be different on different ADS-B data links.*
2. *The heading reference direction (true north or magnetic north) is given in the MS Report (§3.5.1.4).*

3.5.1.6.1 Conditions for Transmitting ARV Report Elements

There are no conditions specified in these MASPS for which it is required to transmit messages supporting ARV reports. Possible future conditions being considered for requiring ARV reports are discussed in Appendix G.

Notes:

1. *Uses of the ARV report are anticipated for future applications such as in-trail spacing, separation assurance when the transmitting aircraft is being controlled to an air-referenced heading, and for precision turns. For example, ARV report information allows wind conditions encountered by the transmitting aircraft to be derived. Current heading also provides a consistent reference when the aircraft is being controlled to a target heading. Such anticipated uses for ARV information are described in Appendix G.*

2. *Such uses will be associated with conditions for transmitting messages to support the ARV report. It is anticipated that when the requirements for such future applications are better understood, that additional conditions for transmitting the ARV report information may be included in a future revision of these MASPS.*

3.5.1.6.2 ARV Report Update Requirements

This section is reserved for update rate requirements when future versions of these MASPS define conditions under which the support of ARV reports is required.

Note: *It is expected that required ARV report update rates will not exceed those for State Vector (SV) reports.*

3.5.1.6.3 Time of Applicability (TOA) Field for ARV Report

The time of applicability relative to local system time **shall (R3.328)** {from 242AR3.121} be updated with every Air-Referenced Velocity report update.

3.5.1.6.4 Airspeed Field

Reported airspeed ranges **shall (R3.329)** {from 242AR3.122} be 0-4000 knots airborne. Airspeeds of 600 knots or less **shall (R3.330)** {from 242AR3.123} be reported with a resolution of 1 knot or finer. Airspeeds between 600 and 4000 knots **shall (R3.331)** {from 242AR3.124} be reported with a resolution of 4 knots or finer.

3.5.1.6.5 Airspeed Type and Validity

The Airspeed Type and Validity field in the ARV report is a 2-bit field that **shall (R3.332)** {from 242AR3.125} be encoded as specified in Table 3-42.

Table 3-42: Airspeed Type Encoding

Airspeed Type	Meaning
0	Airspeed Field Not Valid
1	True Airspeed (TAS)
2	Indicated Airspeed (IAS)
3	Reserved for Mach

3.5.1.6.6 Heading While Airborne Field

An aircraft's heading (§3.2.7) is reported as the angle measured clockwise from the reference direction (magnetic north or true north) to the direction in which the aircraft's nose is pointing. If an ADS-B participant broadcasts messages to support ARV reports, and heading is available to the ADS-B Transmitting Subsystem, then it **shall (R3.333)** {from 242AR3.126} provide heading in those messages. Reported heading range **shall (R3.334)** {from 242AR3.127} cover a full circle, from 0 degrees to (almost) 360 degrees. The heading field in ARV reports **shall (R3.335)** {from 242AR3.128} be communicated and reported with a resolution at least as fine as 1 degree of arc.

Note: *The reference direction for heading (true north or magnetic north) is reported in the True/Magnetic Heading Flag of the Mode Status Report §3.5.1.4.18.*

3.5.1.6.7 Heading Valid Field

The "Heading Valid" field in the ARV report **shall (R3.336)** {from 242AR3.129} be ONE if the "Heading While Airborne" field contains valid heading information, or ZERO if that field does not contain valid heading information.

3.5.1.7 Target State (TS) Report

The Target State (TS) Report provides information on the current status of the MCP/FCU or FMS Selected Altitude and the Selected Heading. Table 3-43 lists the elements of this report.

Table 3-43: Target State (TS) Report Definition

	TS Report Elem. #	Contents [Resolution or # of bits]		Reference Section
ID	1	Participant Address	[24 bits]	§3.2.2.2.1
	2	Address Qualifier	[1 bit]	§3.2.2.2.2
TOA	3	Time of Applicability	[1 s resolution]	§3.5.1.7.3
Selected Altitude	4a	Selected Altitude Type	[1 bit]	§3.5.1.7.4
	4b	MCP/FCU or FMS Selected Altitude	[16 bits]	§3.5.1.7.5
	4c	Barometric Pressure Setting (minus 800 millibars)	[16 bits]	§3.5.1.7.6
Selected Heading	5	Selected Heading	[16 bits]	§3.5.1.7.7
Mode Indicators	6a	Autopilot Engaged	[1 bit]	§3.5.1.7.8
	6b	VNAV Mode Engaged	[1 bit]	§3.5.1.7.9
	6c	Altitude Hold Mode	[1 bit]	§3.5.1.7.10
	6d	Approach Mode	[1 bit]	§3.5.1.7.11
	6e	LNAV Mode Engaged	[1 bit]	§3.5.1.7.12
Reserved		(Reserved for Future Growth)	[4 bits]	

3.5.1.7.1 Conditions for Transmitting TS Report Information

An airborne ADS-B participant of equipage class A2 or A3 **shall (R3.337)** {from 242AR3.130} transmit messages to support the TS Report when airborne, and target state information is available.

Note: *TS Reports are also optional for A1 equipment. If A1 equipment chooses to support TS Reports those reports must meet the requirements specified in §3.5.1.7 and all of its subsections.*

3.5.1.7.2 TS Report Update Requirements

This section is reserved for update rate requirements if future versions of these MASPS should define conditions under which unique update rates may be required to the support TS Reports.

3.5.1.7.3 Time of Applicability (TOA) field for TS Report

The time of applicability relative to local system time **shall (R3.338)** {from 242AR3.132} be updated with every Target State Report update.

3.5.1.7.4 Selected Altitude Type

The “Selected Altitude Type” subfield is a field in the TS Report that is used to indicate the source of Selected Altitude data. Encoding of the “Selected Altitude Type” is specified in Table 3-14.

3.5.1.7.5 MCP/FCU or FMS Selected Altitude Field

The “MCP / FCU Selected Altitude or FMS Selected Altitude” subfield is a field in the TS Report that contains either the MCP / FCU Selected Altitude or the FMS Selected Altitude data as specified in Table 3-15.

3.5.1.7.6 Barometric Pressure Setting (Minus 800 millibars) Field

The “Barometric Pressure Setting (Minus 800 millibars)” subfield is a field in the TS Report that contains Barometric Pressure Setting data that has been adjusted by subtracting 800 millibars from the data received from the Barometric Pressure Setting source. After adjustment by subtracting 800 millibars, the Barometric Pressure Setting is encoded as specified in Table 3-16.

3.5.1.7.7 Selected Heading Field

The “Selected Heading” is a field in the TS Report that contains Selected Heading data encoded as specified in Table 3-19.

3.5.1.7.8 MCP/FCU Mode Indicator: Autopilot Engaged Field

The “Mode Indicator: Autopilot Engaged” subfield is a field in the TS Report that is used to indicate whether the autopilot system is engaged or not, as specified by Table 3-21.

3.5.1.7.9 MCP/FCU Mode Indicator: VNAV Mode Engaged Field

The “Mode Indicator: VNAV Mode Engaged” is a field in the TS Report that is used to indicate whether the Vertical Navigation Mode is active or not, as specified in Table 3-22.

3.5.1.7.10 MCP/FCU Mode Indicator: Altitude Hold Mode Field

The “Mode Indicator: Altitude Hold Mode” is a field in the TS Report that is used to indicate whether the Altitude Hold Mode is active or not, as specified in Table 3-23.

3.5.1.7.11 MCP/FCU Mode Indicator: Approach Mode Field

The “Mode Indicator: Approach Mode” is a field in the TS Report that is used to indicate whether the Approach Mode is active or not, as specified in Table 3-24.

3.5.1.7.12 MCP/FCU Mode Indicator: LNAV Mode Engaged Field

The “Mode Indicator: LNAV Mode Engaged” is a field in the TS Report that is used to indicate whether the Lateral Navigation Mode is active or not, as specified in Table 3-25.

3.5.2 Traffic Information Services – Broadcast (TIS-B) Messages and Reports

The formats and coding for a TIS-B Report are based on the same ADS-B data elements as are defined for each individual ADS-B data link.

Table 3-44: TIS-B Report Definition

Element	Contents [Resolution or # of Bits]	Required for Airborne Targets	Required for Surface Targets	Section	Notes
ID	Target Address [24 bits]	•	•	§3.2.2.2.1	
	Address Qualifier [1 bit]	•	•	§3.2.2.2.2	
	Call Sign [8 alpha-numeric characters]	•	•	§3.2.2.1	1
	Target Category [5 bits]	•	•	§3.2.2.3	1
TOA	Time of Applicability	•	•	§3.5.1.3.3	2, 3
SV	State Vector	•	•	§3.5.1.3	3
Target Quality	Nav. Acc. Category for Position (NAC_P) [4 bits]	•	•	§3.5.1.4.11	
	Nav. Acc. Category for Velocity (NAC_V) [3 bits]	•	•	§3.5.1.4.12	
	Navigation Integrity Category (NIC) [4 bits]	•	•	§3.5.1.3.18	
	Source Integrity Level (SIL) [2 bits]	•	•	§3.5.1.4.13	
	SIL Supplement [1 bit]	•	•	§3.5.1.4.22	
Status	Emergency/Priority Status [3 bits]	•	•	§3.5.1.4.8	
Operational Mode	IDENT Switch Active [1 bit]	•		§3.5.1.4.10	1
	Reserved for Receiving ATC Services [1 bit]	•		§3.5.1.4.10	1
Data Reference	True/Magnetic Heading [1 bit]	•	•	§3.5.1.4.18	
	Vertical Rate Type (Baro/Geo) [1 bit]	•		§3.5.1.4.19	
	Air/Ground State [2 bits]	•	•	§3.5.1.3.1	

Notes:

1. *This field is required only if the information is made available to the TIS-B Subsystem.*
2. *The internal precision for the TOA field is to be determined to meet other requirements, e.g., report time error.*
3. *The Link-Specific Processing subsystem performs extrapolation on position elements of the State Vector. Before this function is performed, TOA refers to Time of Measurement, and afterward, to the time to which the elements are extrapolated.*

3.5.3 ADS-B Rebroadcast Service (ADS-R) Messages and Reports

The formats and coding for a ADS-R Report are based on the same ADS-B data elements as are defined for each individual ADS-B data link.

3.6 External Subsystem Requirements

Ownship subsystems external to ASA include navigation, TCAS, flight management and flight controls, etc. This section provides requirements associated with both the transmit (ADS-B Out) and receive (ADS-B In) functions, and assumptions on the systems external to the ASA system bounds.

3.6.1 Ownship Position Data Source

The availability of ASA is dependent on a source of Ownship position information.

ASSUMP 16: It is assumed that the majority of airborne ASA installations will be equipped with GNSS as the geometric position and velocity data source based on the ability to meet the performance requirements necessary to support installed applications.

At the time these MASPS were written, there are no known non-GNSS position sources (e.g. VOR/DME, DME/DME, Loran, or inertial for position determination) that meet the performance requirements for ASA. It is possible that future development may lead to a non-GNSS position source that can meet the performance requirements for ASA. These alternate position sources may not necessarily meet the criteria for the primary position source, however, it is possible that they can be utilized to update Ownship position during short instances of GNSS intermittency, while it can be determined that the performance requirements for the active application(s) are met.

ASA installations **shall (R3.339)** {new reqmt} be equipped with a source of Ownship geometric position and velocity data.

The same Ownship position source **shall (R3.340)** {new reqmt} be utilized by both “ADS-B In” applications, as well as “ADS-B Out” transmissions.

ASSUMP 17: To qualify for use by ASA, the selected Ownship position data source is assumed to be capable of providing A/V geometric position and velocity data that meets the integrity and accuracy performance requirements.

The Ownship position data will include the following:

- Ownship horizontal position in latitude and longitude referenced to WGS-84 ellipsoid.
- Ownship geometric height above ellipsoid surface, if available.
- The position data accompanied with accuracy and integrity metrics for determination of Navigation Accuracy Category for position (NAC_P) (see §3.2.11) and Navigation Integrity Category (NIC) (see §3.2.10) of the data.
- Individual horizontal position and geometric height validity flags.
- Geometric Vertical Accuracy

The Ownship velocity data **will** include the following:

- Ownship horizontal velocity. The velocity may be provided in rectangular (north/east velocity for airborne operations) or polar (ground speed and track for surface operations) coordinates. When heading is provided, an indication of true/mag reference is required. Heading referenced to true north is preferred.
- Velocity data accompanied with accuracy metrics for determination of Navigation Accuracy Category for velocity (NAC_V) (see §3.2.12) of the data. When a velocity accuracy metric is not output by a source, a qualified means to determine a velocity accuracy should be performed.
- A velocity validity flag.

There **shall (R3.341)** {new reqmt} be a means to determine the SIL value for the Ownship position data source.

There **shall (R3.342)** {new reqmt} be a means to determine when a Ownship position data source has failed so that an acceptable alternate Ownship position source may be selected, if available.

The maximum time to indicate a change in integrity of the Ownship position data outputs will be less than 10 seconds.

3.6.2 Air Data Source

ASSUMP 18: It is assumed that the majority of airborne ASA installations will be equipped with air data sources to provide pressure altitude, pressure altitude rate, barometric pressure setting and air speed, if required.

To qualify for use by ASA, the selected air data source is assumed to meet the following requirements.

Note: *Future versions of these MASPS may require that the airspeed data be broadcast by ADS-B Out, and be available to the ASSAP and CDTI.*

1. The air data source will be capable of providing digital outputs of A/V pressure altitude and pressure altitude rate suitable for surveillance based applications.
2. The pressure altitude data will include the following:
   - Pressure altitude referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in. Hg).
   - Pressure altitude outputs covering the operating altitude range of the A/V.
   - Pressure altitude validity flag.
   - Quantization data to determine if pressure altitude outputs are encoded as 25, or 100 ft.

     Note: *The finer altitude data resolution of 25 ft is preferred.*

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3. The altitude rate data, if available, will include the following:

    - Rate of change of pressure altitude outputs covering the operating altitude rate range of the A/V.
    - Pressure altitude rate validity flag.

    Note: *Complimentary inertial/barometric filtered altitude rate is the preferred source.*

3.6.3 Heading Source

ASSUMP 19: It is assumed that the majority of airborne ASA installations will be equipped with heading data sources to indicate the directional orientation of the A/V.

To qualify for use by ASA, the selected heading data source is assumed to meet the following requirements.

The heading data source will be capable of providing outputs of A/V heading suitable for surveillance based applications.

The heading data source will provide heading outputs supporting the full range of possible headings (e.g. full circle from 0º to 360º).

The heading data source will provide heading with a resolution of 6º of arc or finer.

The heading data source will provide heading with an accuracy of ±10º, or better (95%).

The heading data will include the following:

- Means to determine if A/V heading is referenced to true north or magnetic north.
- Heading validity flag.

3.6.4 TCAS

TCAS interfaces to ASA in two ways: first, if TCAS is installed on an ADS-B transmitting ship, the fact that TCAS is installed, and the TCAS status (e.g., resolution advisory) are included in the ADS-B transmission (§3.2.8.1). The installation and status is reported by the ADS-B receiver (§3.5.1.4.9). If TCAS is installed with ASA, and if the CDTI is also used as the TCAS traffic display, TCAS tracks and their status should be supplied to ASA. TCAS interfaces directly to ASSAP, as indicated in Figure 3-1. Table 3-45 indicates the traffic data that should be interfaced to ASSAP from TCAS.

<u>Table 3-45:</u> TCAS Traffic Data Interface to ASSAP

Data Item [note 4]	Reference Section
TCAS Alert Status	§3.4.1.3
Target Range	§3.4.1.3
Target Bearing	§3.4.1.3
Target Pressure Altitude [note 2]	§3.4.1.3
TCAS Altitude Rate or Vertical Sense [note 3]	§3.4.1.3
Mode S Address [notes 1 and 2]	§3.4.1.3
TCAS Track ID	§3.4.1.3
TCAS Report Time [note 5]	§3.4.1.3

<u>Notes for Table 3-45:</u>

1. *ASSAP that are hosted in the internal TCAS LRU have access to the Mode S (ICAO 24-bit) address (on 1090 MHz Extended Squitter installations).*
2. *For ASSAPs that are hosted externally to TCAS, this information requires a change to the standard TCAS bus outputs defined in ARINC 735B that currently does not provide the Mode S address code, nor does it necessarily output Mode C pressure altitude.*
3. *For display of up/down arrow on the CDTI if there is no ADS-B track that correlates with the TCAS track.*
4. *Range rate and range acceleration may be required in the future.*
5. *Optional capability that may be required in the future.*

3.6.5 Airport Surface Maps

An airport surface map is necessary to support the SURF application for each airport where these applications are used. The subsystem that provides the airport surface maps is external to ASA system boundaries defined in these MASPS.

ASSUMP 20: Airport surface maps are assumed to be encoded into an electronic database. At a minimum, this database is assumed to contain the runways and taxiways within the maneuvering area of the airport.

The features, quality, and reference datum assumptions for this ASA external database are stated in the following sub-sections.

Unless stated otherwise, all of the assumptions within this section including its subsections apply for the SURF application.

3.6.5.1 Features

All airport features shown on the CDTI for the SURF application is based on the airport surface map database. At a minimum, this database is assumed to contain the runways and taxiways within the maneuvering area of the airport.

Other airport features are desired to be represented in the database including, for example, apron areas, stand guidance lines, parking stand areas, deicing areas, clearways, and vertical objects like buildings and towers.

Note 1: *The "maneuvering area" of an airport is defined as the part of an airport used for take-off, landing, and taxiing of aircraft, excluding aprons [reference ICAO Annex 14, section 1].*

All features of the database are assumed to have sufficient information to support:

1. Determining their horizontal position with respect to the WGS-84 reference datum, and

2. Appropriately labeling the feature on the CDTI.

It is further assumed that the vertical position for at least one feature for each airport surface map is given.

Note 2: *Vertical position is used by the SURF application to support determining whether or not a flying aircraft is close enough to the airport surface for SURF situational awareness display purposes.*

3.6.5.2 Quality

Airport surface map database quality is assessed in terms of feature position accuracy, resolution, integrity, and timeliness (currency).

The accuracy, resolution, and integrity quality of the airport surface map database are assumed to comply with at least one of the following:

1. The database requirements specified in RTCA DO-257A [33] (or subsequent revision) for the Aerodrome Moving Map Display (AMMD), or

2. RTCA DO-272C [39] (or subsequent revision) "Medium" or higher quality database standard (see note 1 below), or

3. Database judged by the approval authority to be current and operationally acceptable for the intended application(s).

Note 1: *Airport map database requirements are defined in RTCA DO-272C [39]. RTCA DO-272C [39] defines three categories of airport map data including "Coarse," "Medium," and "Fine." The categories are groupings for the minimum required accuracy, resolution, and integrity quality of the database.*

The database is assumed to be current.

Note 2: *The valid dates of applicability for the airport surface map database are defined by the Aeronautical Information Regulation and Control (AIRAC).*

3.6.5.3 Reference Datum

The airport surface map database **shall (R3.343)** {new reqmt} use WGS-84 as its reference datum.

Note: *There are at least three reasons for using WGS-84 as the reference datum for the airport map. First, international standards require "geographical coordinates indicating latitude and longitude [for airport data] be determined and reported* *to the aeronautical information services authority in terms of WGS-84," according to §2.1.5 in ICAO Annex 14. Thus, the data in WGS-84 is likely to be available. Second, WGS-84 is the coordinate frame required for transmitting traffic position on ADS-B. Third, ownship position is provided to ASSAP/CDTI in WGS-84 reference datum. While it is possible to transform data from one coordinate frame to another, it is required for the standards documents to use a common standard coordinate frame.*

3.6.6 Flight ID Source

ASA receive participants utilize Flight IDs received from ASA transmit participants. The Flight ID of traffic can also be used by crews to unambiguously identify ASA participants on the CDTI. The Ownship Flight ID might be provided by one of many different sources, including; Mode S/TCAS Control Panel, Flight Management System, ACARS, or an Electronic Flight Bag.

The ASA transmit subsystem **shall (R3.344)** {new reqmt} be provided with an Ownship Flight ID of up to 8 characters.

3.6.7 Flight Control System/Mode Control Panel

The ASA installation will be provided with information available from the Flight Control System/Mode Control Panel, which may include; Selected Heading, Selected Altitude, and CAS/Mach display mode indication.

3.6.8 Other External Systems

In the future, ASA may interface with other systems, such as:

- Flight control systems
- FIS-B / Weather and NAS status updates / TIS-B Service status
- Terrain and obstacles
- Addressed data link
- ADS-Contract
- Flight Management Systems for other ASA application data

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3.7 Assumptions

3.7.1 Summary of Assumptions

To achieve the expected gains, this document makes certain assumptions (**ASSUMP #**) about the use of new technology. These Assumptions are summarized in the following table.

Table 3-46: Summary of Assumptions

Assumption Number	Text of the Assumption
ASSUMP 1:	Flight crews, in appropriately equipped aircraft, will be able to perform some functions currently done by ATC, some of which may be at reduced separation standards compared to current separation standards.
ASSUMP 2:	The variability in the spacing between aircraft in the airport arrival and/or departure streams will be reduced with the use of certain ASA applications.
ASSUMP 3:	For the near and mid-term applications, ATC will be willing to act as a "monitor" and retain separation responsibility between designated aircraft.
ASSUMP 4:	Pilot and ATC workload will not be increased substantially by ASA applications.
ASSUMP 5:	Most aircraft will eventually be equipped with avionics to perform ASA applications (this is necessary to maximize system benefits).
ASSUMP 6:	For the far-term applications, pilots may be willing to accept additional separation responsibility beyond what they have today that is currently provided by ATC.
ASSUMP 7:	ADS-B avionics and applications will be compatible with future ATC systems and operating procedures.
ASSUMP 8:	The following assumptions are made about the operational environment for the AIRB application: • The AIRB application can be used by aircraft operating in any airspace class (i.e., A thru G). • The AIRB application can be used by aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR). • The AIRB application can be used under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC). • The AIRB application can be used in airspace of any traffic density. • The ADS-B equipage (i.e., ADS-B Out and ADS-B In) within the deployment environment will be partial. • The AIRB application does not change the roles or responsibilities for controllers in comparison with existing operations. • The AIRB application may be used in regions where only radar surveillance is utilized and can also be used in regions where ADS-B Out ATS surveillance is utilized.

Assumption Number	Text of the Assumption
ASSUMP 9:	The following assumptions are made about the operational environment for the AIRB application: • The VSA application can be used by aircraft flying a visual or an instrument approach. • The VSA application is applicable to single runway, independent parallel runways, dependent parallel runways, and closely-spaced parallel runways. • The VSA application can only be conducted under VMC as defined by ICAO or as specified by the State. • The VSA application can be used by all suitably equipped aircraft during approach to any airports where own visual separation is used. • The airspace in which the VSA application is used has VHF voice as the means of communication between the controllers and flight crews. • The VSA application can be applied in airspace of any traffic density. • The minimum spacing between the preceding aircraft and succeeding aircraft during the Visual Acquisition phase is 3 NM. • At a range of 5 NM, the 95% update interval for both horizontal position and horizontal velocity is assumed to be 3 seconds. • The ADS-B equipage (i.e., ADS-B Out and ADS-B In) within the deployment environment will be partial.
ASSUMP 10:	The ADS-B-APT Target Environment is assumed to be a simple to complex aerodrome layout with many taxiways, possibly multiple terminals and aprons and possibly multiple runways, but limited up to two active runways at a time, with ADS-B as a unique means of surveillance. 100% ADS-B OUT qualified equipage for the aircraft or ground vehicles in the Maneuvering Area is assumed.
ASSUMP 11:	The Total Latency for Ownship position data sources is assumed to be no greater than 1 second from the Time of Measurement (Interface A3) to the time the data is supplied to ASSAP (Interface B3, see Figure 1-1).
ASSUMP 12:	The Total Latency allocation for the navigation subsystem that measures the source position and velocity for the ADS-B transmitting aircraft/vehicle is assumed to be no greater than 0.5 seconds from Interface A1 to A4.
ASSUMP 13:	The Total Latency allocation from Interface A1 to B1 is assumed to be no greater than 0.9 seconds.
ASSUMP 14:	Since the reports generated by the ADS-B Receive Subsystem have a Time of Applicability, it is assumed that any extrapolation of target data by ASSAP/CDTI utilizes that TOA.
ASSUMP 15:	The state vector report is constantly changing and is important to all applications, including the safety critical ones. Algorithms designed to use the state vector reports will assume that the information provided is correct.
ASSUMP 16:	It is assumed that the majority of airborne ASA installations will be equipped with GNSS as the geometric position and velocity data source based on the ability to meet the performance requirements necessary to support installed applications.
ASSUMP 17:	To qualify for use by ASA, the selected Ownship position data source is assumed to be capable of providing A/V geometric position and velocity data that meets the integrity and accuracy performance requirements.
ASSUMP 18:	It is assumed that the majority of airborne ASA installations will be equipped with air data sources to provide pressure altitude, pressure altitude rate, barometric pressure setting and air speed, if required.
ASSUMP 19:	It is assumed that the majority of airborne ASA installations will be equipped with heading data sources to indicate the directional orientation of the A/V.
ASSUMP 20:	Airport surface maps are assumed to be encoded into an electronic database. At a minimum, this database is assumed to contain the runways and taxiways within the maneuvering area of the airport.

3.7.2 GNSS Performance Characteristics Relevant to ADS-B

This section contains information regarding ADS-B performance provided by GNSS. Document references in §3.7.2 are unique to this section and appear in §3.7.2.5. Because performance strongly depends on user equipment characteristics, information regarding GNSS UE ADS-B performance is included. Information is provided in the following areas:

- Which performance characteristics needed for ADS-B Out service are required to be met by existing types of GNSS user equipment.
- Information regarding the information output by GNSS user equipment (e.g., rate of output, meaning of data, time of applicability, and delay of information output) relevant to ADS-B service.
- Availability and continuity of ADS-B Out service and other ADS-B services.
- Other topics.

3.7.2.1 Comparison of Performance Characteristics Needed for ADS-B and Minimum Requirements of Existing Types of GNSS User Equipment

ADS-B service may be provided by several types of GNSS-based user equipment (UE) that exist now or will exist in the future. Types of GNSS UE that currently exist or will exist in the near future and may be used for ADS-B Out service are as follows:

- GPS UE that meets the standards of RTCA/DO-208 [1] as modified by FAA TSO-C129 [2] or C129a [3]
- GPS UE that meets the standards of RTCA/DO-316 [4] and FAA TSO-C196 [5]
- SBAS/GPS UE that meets the standards of RTCA/DO-229C [6] and TSO-C145a [7] or C146a [8]; or of RTCA/DO-229D [9] and TSO-C145b [10], C146b [11], C145c [12], or C146c [13]

GBAS/LAAS UE [14] might also be used for potential future ADS-B applications on the airport surface and in the terminal area, but its coverage does not extend throughout en route airspace.

Existing GPS UE installed on air carrier aircraft was approved using the Type Certification (TC) or Supplemental TC (STC) process and was not approved using the TSO process in many cases. However, the equipment meets most or all of the requirements of one or more of the above TSOs.

FAA Advisory Circular (AC) 20-165 [15] provides guidance for the installation and airworthiness approval of ADS-B Out systems in aircraft. Existing GNSS equipment that meets one or more of the above standards [1-13] does not necessarily support all performance characteristics specified in AC 20-165. RTCA Special Committee 159 conducted a gap analysis that compared the requirements of GPS and SBAS UE equipment to the performance characteristics of AC 20-165. The results are in the form of tables that describe, for each performance characteristic in AC 20-165, whether the characteristic is required to be supported by each type of GPS or SBAS UE. In addition, if the characteristic is not required to be supported, a verification method is described to indicate how a manufacturer may demonstrate that a given model of equipment supports the performance characteristic in AC 20-165. These tables are expected to be approved at the SC-159 plenary meeting on 18 November 2011.

Note: *AC 20-165A is in preparation and will supersede AC 20-165.*

3.7.2.2 Information Regarding Information Output by GNSS User Equipment Relevant to ADS-B Service

Guidance information for interfacing SBAS UE with ADS-B equipment is contained in Appendix U of DO-229D [1]. Similar guidance information for interfacing TSO-C196 UE with ADS-B equipment is contained in Appendix U of DO-316. These MASPS do not contain all information in Appendix U of DO-229D or DO-316. However, a few examples of information from those documents are given below in order to illustrate the types of information contained in them:

- Integrity information output by SBAS UE is in the form of a Horizontal Protection Level (HPL) and a separate alert indication. When SBAS UE is operating in en route, terminal, or LNAV mode, the integrity assurance function can be provided either by SBAS-provided integrity information or by the Receiver Autonomous Integrity Monitoring (RAIM) fault detection (FD) or fault detection and exclusion (FDE) function. In the former case the HPL is called HPLSBAS, and in the latter, HPLFD. The presence of a RAIM-detected alert condition that cannot be excluded (i.e., HPLFD is not assured to bound horizontal position error with the required probability) is not reflected in the size of HPLFD. Instead, the alert condition is reflected in a separate alert flag or parameter output by the UE, which must be used by ADS-B equipment to set the position output to “invalid”.

- SBAS UE may not indicate whether the HPL that is output is HPL¬SBAS or HPLFD. But when in en route through LNAV modes, both HPLs bound horizontal radial position error with a probability of $1 – 10^{-7}$ per hour.

- When SBAS UE is in LNAV/VNAV, LPV, or LP mode, the HPL that is output bounds horizontal position error (HPE) with a probability of $1 – 2 \times 10^{-7}$ per approach, where an approach duration is assumed to be 150 seconds. If the SBAS UE does not have an indication of the mode, the ADS-B equipment assumes that the SBAS UE has multiplied HPL by 1.03 in order to account for the possibility that SBAS UE is in LNAV/VNAV, LPV, or LP mode, and ensure that the HPL bounds HPE with a probability of $1 – 10^{-7}$ per hour.

- The “time of applicability” associated with the position output will be within 200 ms of the time of the output. An aircraft flying, for example, 250 knots ground speed travels about 26 meters in 200 ms, which might be significant for some

[1] Note that although Section U.1 of DO-229D states that all classes of equipment compliant with DO-229D are expected to satisfy the requirements for initial U.S. applications of ADS-B, a few requirements in AC 20-165 (e.g., Integrity Validity Limit, Velocity Accuracy, output of Height Above Ellipsoid, and others) are not minimum requirements of DO-229D or DO-316 UE. The matrices referred to in Section 3.7.2.1 of these MASPS describe the requirements gaps. ➔ DOES RTCA HAVE INTENTION TO PUBLISH THIS ?? ➔

applications. Compensation of position from this position to the ADS-B position must be accomplished by the ADS-B equipment.

- The latency (delay) in HPL reflecting a fault condition for en route through LNAV flight can be as much as 8 seconds.

- When RAIM FD is used to assure integrity, DO-229D and DO-316 UE might output an HPL that is less than 0.1 nautical miles (NM), but if SBAS ionospheric corrections and associated error bounds are not applied (always true for DO-316 UE), the HPL is not assured to bound HPE with a probability of $1 - 10^{-7}$. This is because the ionospheric error model associated with the use of GPS single-frequency ionospheric corrections has not been validated to levels below about 0.1 NM.

Information similar to that provided in Appendix U for DO-229D and DO-316 UE has not been compiled for TSO-C129/129a UE. Principal differences between DO-316 UE and equipment complying with only the minimum requirements of TSO-C129 or C129a are listed in the gap matrices referred to in §3.7.2.1 and in §3.7.2.3.

3.7.2.3 ADS-B Availability and Continuity Provided by GNSS User Equipment

The level of availability and continuity of ADS-B Out service experienced by GPS user equipment depends strongly on certain GPS and SBAS performance characteristics [16, 17, 18]. The U.S. government commitment on GPS constellation performance is described in the GPS Standard Positioning Service (SPS) Performance Standard (PS) [19]. Key performance commitments are in the following areas:

- <u>Availability:</u> the number and orbital locations of useable (operational-healthy) GPS satellites. The GPS SPS PS assures that at least 21 of 24 defined orbital plane/slot position will be filled with operational-healthy (useable) satellites (or, when the constellation is in an expanded slot configuration, satellite pairs) with a probability of at least 98%. The PS also assures that at least 20 of 24 defined plane/slot positions will be filled with operational-healthy satellites (or, in an expanded slot configuration, satellite pairs) with a probability of at least 99.999%. (The PS further states that the probability that the constellation will have at least 24 operational satellites is at least 95%, but those satellites may not be useable, and may not be in defined plane/slot positions.)

- <u>Continuity:</u> the probability of an unpredicted satellite signal outage. The SPS PS assures that the average probability of not losing a useable satellite signal due to an unscheduled failure is at least 0.9998 over any hour, given that the satellite signal is available at the beginning of the hour. This is equivalent to a 5000 hour mean time between unscheduled outages of a given satellite. An earlier 2001 version of the SPS PS states that the historical frequency of unscheduled "downing events" was 0.9 per satellite per year, equivalent to a 9700 hour mean time between unscheduled outages. The most recent PS contains no commitment on the probability of not losing a satellite signal due to an unscheduled maintenance action, but no such events are known to have occurred. An outage is unscheduled if it is not announced in a Notice Advisory to Navstar Users (NANU) at least 48 hours in advance. Any loss of a useable signal exceeding 10 seconds is considered an outage.

GPS Block IIA satellites are known to experience a loss of useable signal of one satellite in the entire constellation for a period of 6 seconds about once every month or two, during uploads. Such events have not been observed on Block IIR, IIR-M, or IIF satellites and are not expected to occur on future satellites.

- Signal-in-space (SIS) user range error (URE) accuracy. The SPS PS assures that the root-mean-square (RMS) satellite pseudorange data set error will be less than or equal to 4 meters. Ionospheric error, the largest source of error for SPS users, is not counted in this commitment. In recent years, the actual GPS SIS RMS error (excluding ionospheric error) is less than 1 meter.

  Ionospheric error at the GPS L1 frequency is generally small (a few meters or less), but during ionospheric storms near the maximum of the 11-year solar cycle, ionospheric range delay experienced by users within about 30 degrees of earth's magnetic equator to satellites at low elevation angles can be approximately 150 meters. The GPS single-frequency ionospheric correction model is likely to correct 50% or more of the error.

- SIS user range rate error (URRE) accuracy. The SPS PS assures that the 95% global average user range rate error over any 3-second interval during normal operations will be less than or equal to 0.006 meters/second for operational-healthy satellites. Ionospheric error is excluded.

Note that these commitments are stated in the range domain, whereas what is of interest to ADS-B users is performance in the position domain, e.g., availability of a NIC of 7 or of a NAC_P of 8.

The US government commitment on WAAS performance is described in the WAAS Performance Standard [20]. Performance is described in the position domain for phases of flight including en route, terminal, LNAV, and LPV service in each of five Zones. Examples of WAAS performance commitments include an availability of 99.999% and continuity of $1 - 10^{-5}$ per hour for a HAL of 0.3 NM in CONUS. No defined level of WAAS service corresponds exactly to NIC = 7, or a $NAC_P = 8$.

The providers of other GNSS core constellations (e.g., GLONASS, Galileo) or other SBASs (e.g., MSAS, EGNOS) have not yet published Performance Standards.

Besides depending strongly on GPS and SBAS performance, the level of availability and continuity of ADS-B Out service also depends strongly on the characteristics of GNSS UE. For the purpose of this subsection, GNSS UE may be grouped into three main categories, with availability and continuity characteristics being similar with each category:

- The first category is "SA-unaware" GPS UE. Selective Availability (SA), an intentional degradation of GPS range and position error, was set to zero by the US Department of Defense on May 1, 2000. However, some GPS UE on existing aircraft still use RAIM algorithms that are based on the assumption that SA is "ON". TSO-C129/129a UE RAIM algorithms are commonly based on the assumption that SA is "ON" and that the standard deviation of GPS pseudorange error is large (33.3 meters). The consequence is that RAIM availability is significantly lower for such equipment compared to the other categories of GNSS UE. Figure 3-18 shows the availability of a NIC of 7 (HAL = 0.2 NM) for a particular set of assumptions on GPS constellation satellite performance;

estimated average availability of a NIC of 7 is less than 90% in many US locations. The assumptions on GPS constellation performance are consistent with the US government commitment on GPS constellation performance in the GPS SPS PS [19] described above. Historical GPS constellation performance has far exceeded the minimum commitment in the GPS SPS PS, but there is no assurance that future constellation performance will continue to be as good as historical performance. The results shown are based on a 2º user equipment mask angle.

TSO-C129 and C129a UE is not required to have the receiver autonomous fault exclusion function. If a GPS integrity anomaly occurs during flight, TSO-C129/129a UE may declare a RAIM alert and be unable to exclude the malfunctioning satellite’s range measurement from the user position solution. Aircraft with TSO-C129/129a user equipment are required to have another means of navigation. However, the other means of navigation may not support ADS-B Out requirements. Thus, the aircraft may need to revert to backup procedures when in ADS-B airspace. According to the 2008 GPS SPS PS, approximately 3 GPS integrity anomalies may occur in the entire constellation per year on average. Because approximately one-third of the satellites are in view of a given user location at any given time, such an event might occur about once per year. All aircraft that have TSO-C129/129a UE and that are using the faulty satellite may experience an unexcludable fault at the same time. A frequency of once per year is equivalent to a probability of about 1.1×10^{-4} per hour.

- The second category of GNSS UE is “SA-aware” GPS UE. A majority of GPS UE on existing air carrier aircraft and DO-316 UE takes advantage of the fact that SA has been set to zero, and consequently experiences higher availability than “SA-unaware” GPS UE. DO-316 is also required to have the fault exclusion function; other “SA-aware” GPS UE also have it. Figure 3-18 shows that under a GPS constellation assumption consistent with the US government commitment in the GPS SPS PS, averaged estimated availability be between 99% and 99.9% in the U.S. Estimated availability is significantly higher if the GPS constellation performance is consistent with historical levels. But as stated previously, future GPS constellation performance may not be consistent with historical levels. The results shown are based on a 2º user equipment mask angle.

- The third category of GNSS UE is SBAS UE. SBAS UE provides significantly increased availability compared to GPS UE in areas of SBAS coverage, if other factors are equal. This is because the SBAS integrity assurance function requires only 4 SBAS-monitored ranging sources. In contrast, GPS UE requires the use of the RAIM function detection function to assure integrity, which requires a minimum of 5 ranging sources. In addition, SBASs provides clock, ephemeris and ionospheric corrections, which reduce error and provide service in conditions of poorer user-to-satellite geometry (dilution of precision). Furthermore, some SBAS (WAAS and MSAS) geostationary satellites provide a GPS-like ranging function, reducing dependence on GPS. Estimated average WAAS availability is shown in Figure 3-18 and exceeds 99.99% in the U.S. Results are based on the following assumptions:

- GPS constellation performance assumptions are the same as for the other availability analyses.
- It is assumed that two WAAS geostationary satellites are operating; currently WAAS has three geostationary satellites.
- Results are shown for SBAS Class 1 UE that does not apply WAAS ionospheric corrections, but instead uses the GPS single-frequency ionospheric correction model. Estimated availability would be significantly higher for WAAS UE that applies WAAS ionospheric corrections.
- UE has a 2° mask angle.

Results are not shown for the range of GNSS UE characteristics that have a significant effect on availability. Availability is significantly smaller for UE with a higher mask angle such as 5° or 7.5°.

Other equipment characteristics that vary across UE are the presence of barometric altimeter aiding and whether UE uses carrier smoothing to reduce pseudorange noise and multipath. Barometric altimeter aiding significantly improves availability for HALs larger than the value of 0.2 NM associated with a NIC of 7, but the effect is not as significant for a HAL of 0.2 NM. The use of smaller airborne multipath and noise error models associated with carrier smoothing has little effect on availability of a HAL of 0.2 NM. However, carrier smoothing may have a large effect on the availability of a NAC of 9 or 10 required for certain potential future ADS-B applications [21, 22].

3.7.2.3.1 Comments on Availability of Accuracy (NAC_P)

The size of HPE provided by all types of GNSS UE is significantly smaller than 92.6 m, the 95% HPE associated with the ADS-B Out NAC_P 8 constraint. However, due to conservatism of the error assumed for SA in SA-unaware UE and conservatism of the ionospheric error model associated with the use of GPS single-frequency ionospheric corrections in SA-aware and minimum Class 1 SBAS UE, the horizontal figure of merit (HFOM) and equivalently, the NAC_P, are sometimes larger than the 95th percentile of HPE (under conditions of poor user-to-satellite geometry). Of the various MOPS, only DO-253A specifies a method of computing HFOM. It is possible that future versions of DO-229 or DO-316 may specify an optional less conservative method of computing HFOM than using the conservative ionospheric error model developed for the high-integrity navigation application.

3.7.2.4 Other Topics

3.7.2.4.1 Vulnerability to Radio Frequency Interference (RFI)

GNSS signals are vulnerable to radio frequency interference (RFI). RFI could affect a significant number of aircraft simultaneously, depending on the height and power of the interferer.

3.7.2.4.2 Future GNSS User Equipment

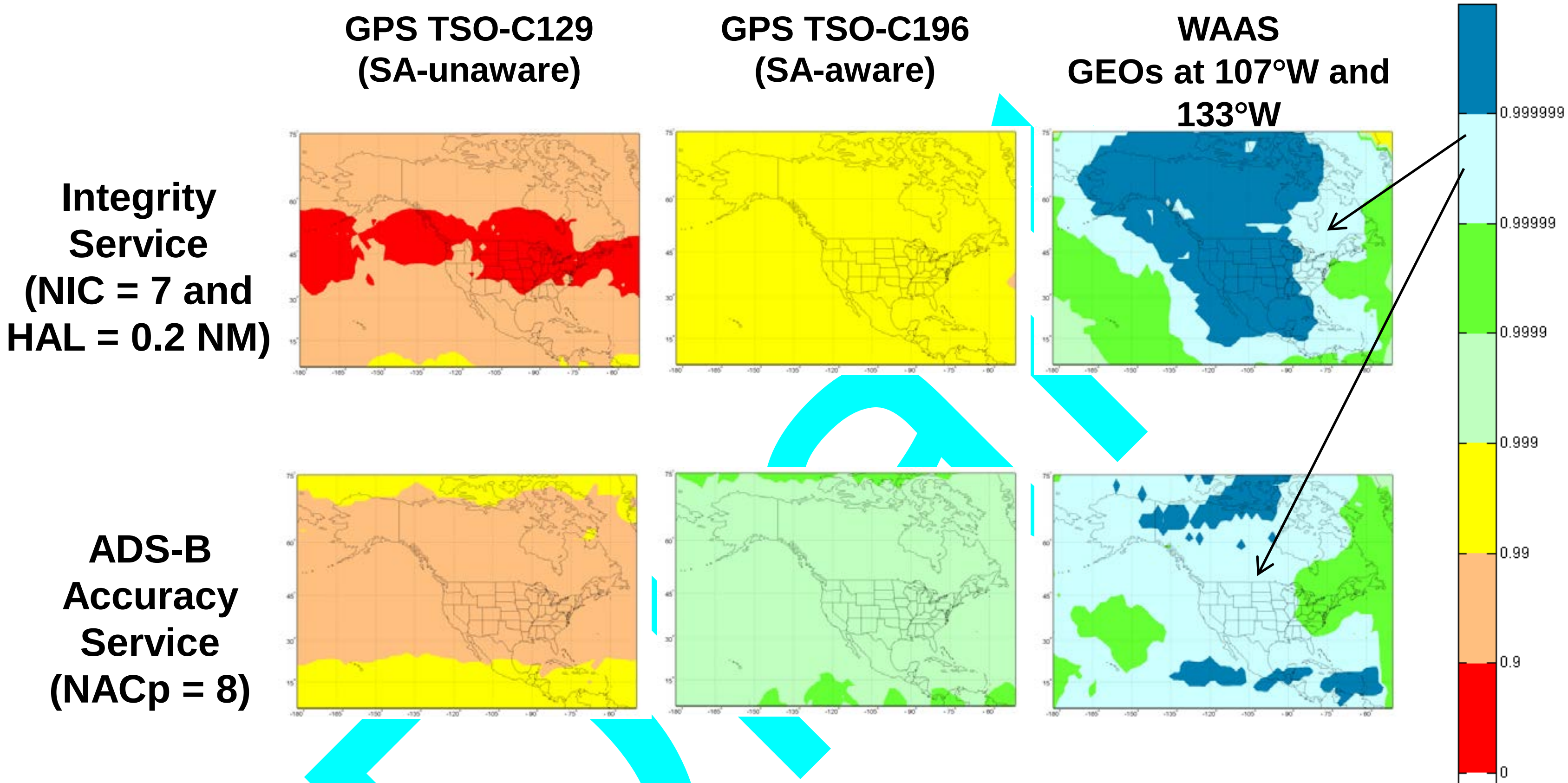
The types of UE described in Refs. 1-13 are sometimes referred to as “single-frequency” because they use only the L1 signal broadcast by GPS and SBAS satellites. The center frequency of the L1 signal is 1575.42 MHz. Some future GNSS user equipment is expected to use not only the L1 signal broadcast by current satellites, but also the L5 signal broadcast by two recently launched and all future GPS satellites and by many future SBAS satellites. The center frequency of the L5 signal is 1176.42 MHz. The use of signals at two frequencies will enable GNSS UE to solve for and virtually eliminate ionospheric delay from GNSS satellite measurements, increasing availability. The second frequency will also provide service in case of radio frequency interference (RFI) affecting only a single frequency.

Future types of GNSS UE that may support ADS-B including the following:

- Dual-frequency GPS UE
- Dual-frequency GPS/Galileo UE
- Dual-frequency SBAS/GPS/Galileo UE
- UE using the Chinese COMPASS, Russian GLONASS, Indian INRSS, or Japanese QZSS systems

3.7.2.4.3 Lack of a Validated Error Model for the Airport Surface

NAC_P for ADS-B Out is derived from the HFOM output by user equipment. The HFOM output by GNSS user equipment is derived using a multipath error model that was validated for airborne flight. Multipath for ground applications is generally larger than in flight. During flight, small changes in aircraft attitude tend to cause multipath error to change quickly and average out when carrier smoothing is done. In addition, the path length of the reflected signal tends to be smaller in flight than on the ground. A ground multipath error model should be developed and validated.



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5994 **Figure 3-18: Average Estimated Availability of NIC=7 and NAC$_P$ =8 for Three Types of GNSS User Equipment Given a 2º User**
5995 **Equipment Mask Angle and GPS Constellation Performance Consistent with the GPS Standard Positioning Service (SPS)**
5996 **Performance Standard (PS)**

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3.7.2.5 References Specific to GNSS Performance Characteristics Relevant to ADS-B

1. Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS), RTCA/DO-208, July 1991, prepared by RTCA Special Committee 159.

2. “Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS),” Technical Standard Order (TSO) C-129, 10 December 1992, U.S. Federal Aviation Administration, Washington, D.C.

3. “Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS),” Technical Standard Order (TSO) C-129a, 20 February 1996, U.S. Federal Aviation Administration, Washington, D.C.

4. Minimum Operational Performance Standards for RTCA DO-316 for Global Positioning System/Aircraft Based Augmentation System Airborne Equipment, DO-316, 14 April 2009, prepared by RTCA Special Committee 159.

5. “Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation,” Technical Standard Order (TSO) C196, effective 21 September 2009, Federal Aviation Administration, Washington, D.C.

6. Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, RTCA/DO-229C, 28 November 2001, prepared by RTCA Special Committee 159.

7. “Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS),” TSO C145a, 19 September 2002, U.S. Federal Aviation Administration, Washington, D.C.

8. “Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS),” TSO C146a, 19 September 2002, U.S. Federal Aviation Administration, Washington, D.C.

9. Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, RTCA/DO-229D, prepared by RTCA Special Committee 159, December 13, 2006, as amended by “Errata to RTCA/DO-229D,” RTCA Paper No. 158-08/SC159-964, July 31, 2008.

10. “Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System,” TSO C145b, 14 February 2007, U.S. Federal Aviation Administration, Washington, D.C.

11. “Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System,” TSO C146b, 14 February 2007, U.S. Federal Aviation Administration, Washington, D.C.

12. “Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System,” TSO-C145c, 2 May 2008, U.S. Federal Aviation Administration, Washington, D.C.

13. “Stand-Alone Airborne Navigation Equipment Using The Global Positioning System Augmented By The Satellite Based Augmentation System,” TSO-C146c, 9 May 2008, U.S. Federal Aviation Administration, Washington, D.C.

14. Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment, RTCA/DO-253C, 16 December 2008, prepared by RTCA Special Committee 159.

15. “Airworthiness Approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out Systems,” Advisory Circular 20-165, 21 May 2010, U.S. Federal Aviation Administration, Washington, D.C.

16. Report from the ADS-B Aviation Rulemaking Committee to the Federal Aviation Administration, September 26, 2008, available from http://www.faa.gov/nextgen/portfolio/trans_support_progs/adsb/media/arcReport2008.pdf

17. D. Hashemi, T. Hsiao, and R. Lejeune, “Availability of Selected ADS-B Services in North America,” May 2009, provided to RTCA SC-186 by MITRE Corporation.

18. Matt Harris, Dean Miller, and Tim Murphy, “Impact of Constellation Health on ADS-B Service Availability,” Proceedings of the 2010 International Technical Meeting of the Institute of Navigation, San Diego CA, January 25-27, 2010, pp. 329-343.

19. GPS Standard Positioning Service Performance Standard, U.S. Department of Defense, 4th edition, September 2008.

20. Global Positioning System Wide Area Augmentation System (WAAS) Performance Standard, 1st edition, 31 October 2008, U.S. Department of Transportation and Federal Aviation Administration.

21. Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications System (ASAS), RTCA/DO-317, 14 April 2009, prepared by RTCA Special Committee 186.

22. Safety, Performance and Interoperability Requirements Document for Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA), RTCA/DO-323, 8 December 2010, prepared by RTCA Special Committee 186.

4 ADS-B IN System Applications Requirements

4.1 Basic Airborne Situation Awareness (AIRB)

CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window and provide traffic situational awareness beyond visual range. The CDTI can be used to initially acquire traffic or as a supplement to other sources of traffic information. The AIRB application is expected to improve both safety and efficiency by providing the flight crew enhanced traffic awareness. The AIRB application also provides Flight ID and ground speed of selected traffic. Refer to RTCA DO-319 [51] (EUROCAE ED-164) for a complete AIRB description.

A basic version of the application, Enhanced Visual Acquisition (EVAcq), is defined in RTCA DO-317A [49] (EUROCAE ED-194) to support the most basic General Aviation users. In this application, CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window. The CDTI can be used to initially acquire traffic or as a supplement to other sources of traffic information. This application is expected to improve both safety and efficiency by providing the flight enhanced traffic awareness.

4.2 Visual Separation on Approach (VSA)

The CDTI is used to assist the flight crew in acquiring and maintaining visual contact during visual separation on approach. The CDTI is also used in conjunction with visual, out-the-window contact to follow the preceding aircraft during the approach. The VSA application is expected to improve both the safety and the performance of visual separation on approach. It may allow for the continuation of visual separation on approach when they otherwise would have to be suspended because of the difficulty of visually acquiring and tracking the other preceding aircraft. Refer to RTCA DO-314 [48] (EUROCAE ED-160) for a complete VSA description.

4.3 Basic Surface Situational Awareness (SURF)

In this application, the CDTI includes an airport surface map underlay, and is used to support the flight crew in making decisions about taxiing, takeoff and landing. This application is expected to increase efficiency of operations on the airport surface and reduce the possibility of runway incursions and collisions. Refer to RTCA DO-322 [53] (EUROCAE ED-165) for a description of the SURF application.

4.4 In Trail Procedures (ITP)

The objective of the In-Trail Procedure (ITP) is to enable aircraft that desire flight level changes in procedural airspace to achieve these changes on a more frequent basis, thus improving flight efficiency and safety. The ITP achieves this objective by permitting a climb-through or descend-through maneuver between properly equipped aircraft, using a new distance-based longitudinal separation minimum during the maneuver. The ITP requires the flight crew to use information derived on the aircraft to determine if the initiation criteria required for an ITP are met. The initiation criteria are designed such that the spacing between the estimated positions of own ship and surrounding aircraft is no closer than an approved distance throughout the maneuver. ITP requires specific application-unique processing and display parameters. Refer to RTCA DO-312 [47] (EUROCAE ED-159) for a complete ITP description.

4.5 Interval Management

4.5.1 FIM

Airborne Spacing - Flight Deck Interval Management (ASPA-FIM) (as defined in RTCA DO-328) describes a set of airborne (i.e., flight deck) capabilities designed to support a range of Interval Management (IM) Operations whose goal is precise inter-aircraft spacing. IM is defined as the overall system that enables the improved means for managing traffic flows and aircraft spacing. This includes both the use of ground and airborne tools, where ground tools assist the controller in evaluating the traffic picture and determining appropriate clearances to merge and space aircraft efficiently and safely, and airborne tools allow the flight crew to conform to the IM Clearance.

IM requires a controller using IM to provide an IM Clearance. While some IM Clearances will keep the IM Aircraft on its current route and result only in speed management, other clearances may include a turn for path lengthening or shortening. The objective of the IM Clearance is for the IM Aircraft to achieve and/or maintain an Assigned Spacing Goal relative to a Target Aircraft. The key addition to current operations is the provision of precise guidance within the flight deck to enable the flight crew to actively manage the spacing relative to the Target Aircraft. During IM Operations, the controller retains responsibility for separation, while the flight crew is responsible for using the FIM Equipment to achieve and/or maintain the ATC Assigned Spacing Goal. This does not differ greatly from current operations when controllers provide speed and turn clearances to manage traffic. With ASPA-FIM, however, the flight crew has the capabilities and responsibility to actively manage the speed of the aircraft to meet the operational goals set by the controller. Enabling flight crews to manage their spacing using the FIM Equipment is expected to reduce controller workload related to the IM Aircraft by relieving the controller of the need to communicate several speed and/or vector instructions.

4.5.2 GIM-S

In response to projected increases in air traffic volume and complexity for the National Airspace System (NAS), applications for Interval Management (IM) are being developed to enhance interval management, including merging and spacing operations in en route and terminal areas for the near-term and mid-term timeframes. These applications include Flight deck-based IM (FIM), in which the flight crew makes use of specialized avionics that provides speed and turn commands. The utilization of FIM in the NAS presupposes the existence of appropriate and integrated Ground-based IM (GIM) capabilities that provides controllers the capabilities to initiate, monitor, and terminate FIM-S operations as well as manage non FIM equipped flights. During IM operations, responsibility for separation may reside with the controller (referred to as spacing applications or GIM/FIM-S) or with the flight crew (referred to as delegated separation applications or GIM/FIM-DS). Figure 4-1 provides an overview of the various applications that can be part of IM.

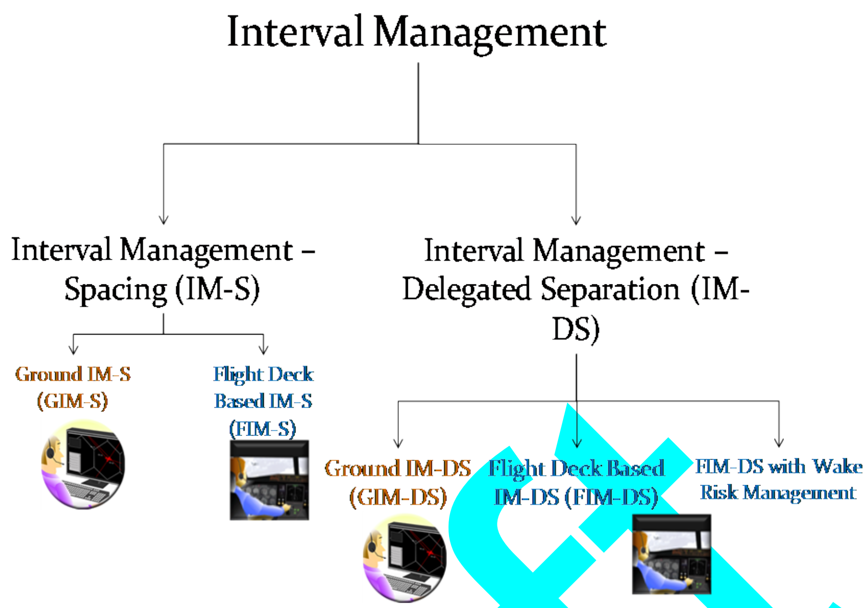


Figure 4-1: Overview of IM Applications

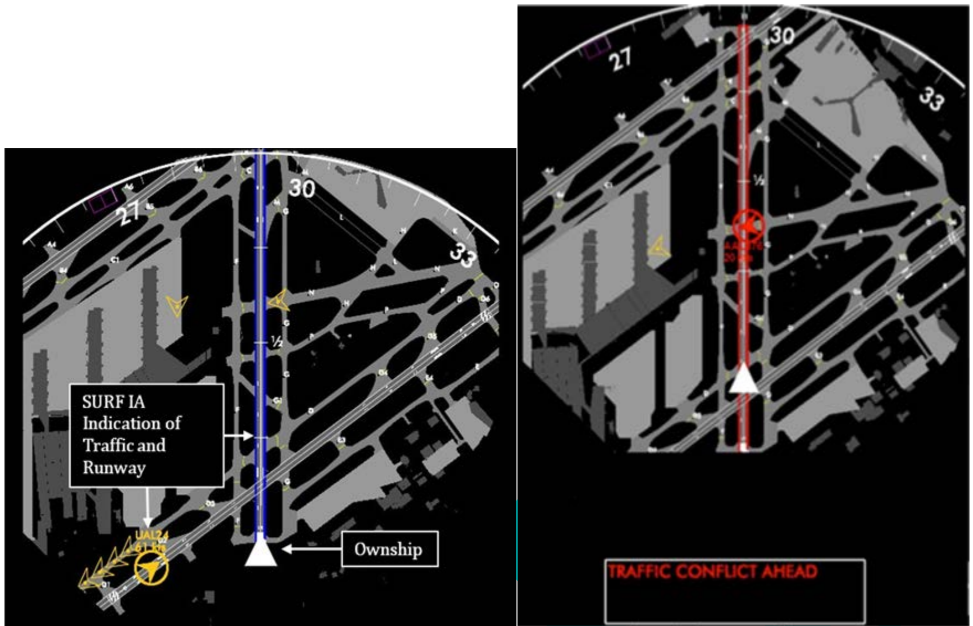
GIM-S applications, either together with the use of FIM-S or by itself, improve aircraft spacing during departure, arrival, and cruise phase of flight. The GIM-S applications assist in reducing the effect of airborne congestion, while increasing runway throughput, and increase the efficiency and capacity of interval management, including merging and spacing operations. The GIM-S application utilizes Automatic Dependent Surveillance – Broadcast (ADS-B) that increases accuracy in trajectory prediction and facilitates more efficient spacing control through the use of speed advisories. While GIM-S can be operated without FIM-S, benefits are expected to increase with the participation of FIM-S aircraft to deliver aircraft at higher accuracy, consistency, and at comparable or lower controller workload.

4.6 Future Applications

4.6.1 Airport Surface with Indications and Alerts (SURF-IA)

The Airport Surface with Indications and Alerts (SURF IA) application enhances the basic SURF application (as described in RTCA DO-322 [53] and EUROCAE ED-165) to increase its effectiveness in preventing runway incursions. The SURF IA application adds two distinct components to the basic SURF for that purpose, (1) SURF IA indications and (2) SURF IA alerts.

SURF IA indications identify the runway status and traffic status that could represent a safety hazard. SURF IA indications are presented under normal operational conditions, do not require immediate flight crew awareness, and do not include auditory and visual attention getters. Secondly, SURF IA alerts are displayed to attract the flight crews' attention to non-normal surface traffic conditions. SURF IA alerts facilitate a timely response via auditory and visual attention getters. SURF IA alerts are non-directive and do not provide guidance about how to respond to the alert. See Figure 4-2 for a notional example of displays. SURF IA indications and alerts include the display of off-scale indications for safety relevant traffic that would otherwise not be visible on the display.



<u>Figure 4-2:</u> Example for SURF IA Indication (left) and A SURF IA warning alert (right)

SURF IA is applicable for operations at controlled and uncontrolled airports and designed for installation on airplanes. SURF IA indications and alerts are supplemental to existing means and procedures of maneuvering aircraft on and near an airport.

SURF IA is described in RTCA DO-323 [54], which contains the detailed safety, performance, and interoperability requirements for the application. RTCA DO-323 [54] requires ADS-B IN, but does not require ground infrastructure such as Traffic Information Service – Broadcast (TIS-B) or Automatic Dependent Surveillance Rebroadcast (ADS-R). However, SURF IA will utilize that surveillance information if available at sufficient quality and integrity.

4.6.2 Traffic Situational Awareness with Alerts (TSAA)

The intended function of TSAA is to provide timely alerts of qualified airborne traffic in the vicinity in order to increase flight crew traffic situation awareness. TSAA is intended to reduce the risk of a near mid-air or mid-air collision by aiding in visual acquisition as part of the flight crew’s existing see-and-avoid responsibility. This application is intended for use by the general aviation community.

TSAA provides alerts using voice annunciations and visual attention-getting cues to direct attention out the window, assisting the flight crew with visual acquisition in suitable meteorological conditions. Indications of Nearby Airborne Traffic are also provided on a Traffic Display (if available). The application functions under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). TSAA alerts and indications are for detected airborne conflicts and relevant nearby traffic status, respectively. When a Traffic Display is available, it builds on the Enhanced Visual Acquisition (EVAcq) or Basic Airborne Situational Awareness (AIRB) application. TSAA is also capable of providing alerts when a Traffic Display is not installed.

Nearby Airborne Traffic indications assist the flight crew in prioritizing activities and are expected to occur for normal traffic situations. The caution level alerts act as attention-getting mechanisms that may reduce the effort required to scan the Traffic Display (if available). They may also reduce the effort required to locate the Target Aircraft while still permitting the flight crew to determine the severity of a conflict and the appropriate action.

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Appendix A
Acronyms and Definitions of Terms

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A Acronyms and Definitions of Terms

A.1 Acronyms

The following acronyms and symbols for units of measure are used in this document.

1090ES	1090 MHz Extended Squitter
A/S	Adjacent Ship
A/V	Aircraft/Vehicle
AC	Aviation Circular (FAA)
AC	Aircraft
ACAS	Airborne Collision Avoidance System. (ACAS is the ICAO standard for TCAS)
ACL	ASA Capability Level
ACM	Airborne Conflict Management
ADS	Automatic Dependent Surveillance
ADS-A	Addressed ADS
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	ADS-Contract
ADS-R	ADS-B – Rebroadcast
AGC	Automatic Gain Control
AGL	Above Ground Level
AIC	Aeronautical Information Circular
AILS	Airborne Information for Lateral Spacing
AIM	Aeronautical Information Manual, (FAA publication)
AIWP	Applications Integrated Work Plan
ALPA	Air Line Pilots Association
AMASS	Airport Movement Area Safety Systems
AMMD	Aerodrome Moving Map Display (an acronym from [DO-257A])
ANSD	Assured Normal Separation Distance
AOC	Aeronautical Operational Control
AOC	Airline Operations Center
AOPA	Aircraft Owners and Pilots Association
APU	Auxiliary Power Unit
ARFF	Aircraft Rescue and Fire Fighting
ARTCC	Air Route Traffic Control Center
ARV	Air Referenced Velocity
ASA	Aircraft Surveillance Applications (to be distinguished from Airborne Surveillance Applications which not referenced as ASA in this document)
ASAS	(1) Airborne Separation Assurance System (an acronym used in [PO-ASAS]) or (2) Aircraft Surveillance Applications System (an acronym used in these MASPS). The two terms are equivalent.
ASDE-3	Airport Surveillance Detection Equipment version 3
ASDE-X	Airport Surveillance Detection Equipment X-band
ASF	Air Safety Foundation (AOPA organization)
ASIA	Approach Spacing for Instrument Approaches
ASOR	Allocation of Safety Objectives and Requirements
ASRS	Aviation Safety Reporting Service
ASSA	Airport Surface Situational Awareness
ASSAP	Airborne Surveillance and Separation Assurance Processing

AT	Air Traffic
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automated Terminal Information System
ATM	Air Traffic Management
ATP	Airline Transport Pilot (rating)
ATS	Air Traffic Services
ATSA	Airborne Traffic Situational Awareness
ATSP	Air Traffic Service Provider
A/V	Aircraft or Vehicle
BAQ	Barometric Altitude Quality
Bps	Bits per Second
CAASD	Center for Advanced Aviation System Development
CARE	Co-operative Actions of R&D in EUROCONTROL
CAZ	Collision Avoidance Zone
CC	Capability Class
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CDTI	Cockpit Display of Traffic Information
CDU	Control and Display Unit
CDZ	Conflict Detection Zone
CFR	Code of Federal Regulations
CNS	Communications, Navigation, Surveillance
CP	Conflict Prevention
CPA	Closest Point of Approach
CPDLC	Controller Pilot Data Link Communications
CR	Conflict Resolution
CRC	Cyclic Redundancy Check
CRM	Crew Resource Management
CSPA	Closely Spaced Parallel Approaches
CTAF	Common Traffic Advisory Frequency
CTAS	Center TRACON Automation System
DAG	Distributed Air Ground
DGPS	Differential GPS
DH	Decision Height
DME	Distance Measuring Equipment
DMTL	Dynamic Minimum Trigger Level
dps	Degree per Second
DOT	Department of Transportation, U. S. Government
ECAC	European Civil Aviation Conference
ELT	Emergency Locator Transmitter
EMD	Electronic Map Display
EPU	Estimated Position Uncertainty
ERP	Effective Radiated Power
ES	Extended Squitter
ETA	Estimated Time of Arrival
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
EVAcq	Enhanced Visual Acquisition

EVApp	Enhanced Visual Approach
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FAROA	Final Approach and Runway Occupancy Awareness
FAST	Final Approach Spacing Tool
FEC	Forward Error Correction
FFAS	Free Flight Airspace
FIS-B	Flight Information Services - Broadcast
FL	Flight Level
FMEA	Failure Modes and Effects Analysis
FMS	Flight Management System
fpm	Feet Per Minute
FRUIT	False Replies Unsynchronized in Time (also see Garble)
FSDO	Flight Standards District Office (FAA)
FSS	Flight Service Station
ft	Feet
g	Acceleration due to earth's gravity
GA	General Aviation
GBAS	Ground-Based Augmentation System
GHz	Giga Hertz
GLONASS	Global Orbiting Navigation Satellite System
GLS	GNSS Landing System
gnd	Ground
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	Ground-based Surveillance Application
GVA	Geometric Vertical Accuracy
HFOM	Horizontal Figure Of Merit
HGS	Head-Up Guidance System
HIRF	High Intensity Radiated Field
HMI	Hazardously Misleading Information
HPL	Horizontal Protection Limit
HUD	Head-Up Display
Hz	Hertz
IAC	Instantaneous Aircraft Count
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
ICR	Integrity Containment Risk
ICSPA	Independent Closely Spaced Parallel Approaches
ID	Identification
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
ITC	In-Trail Climb
ITD	In-Trail Descent
ITU	International Telecommunication Union

JTIDS	Joint Tactical Information Distribution System
kg	Kilogram
LA	Los Angeles
LAAS	Local Area Augmentation System
LAHSO	Land And Hold Short Operations
lb	Pound
LL	Low Level
LOS	Loss of Separation
LSB	Least Significant Bit
m	meter (or “metre”), the SI metric system base unit for length
MA	Maneuver Advisory
MAC	Midair Collision
MACA	Midair Collision Avoidance
MAS	Managed Airspace
MASPS	Minimum Aviation System Performance Standards
MCP	Mode Control Panel
MFD	Multi-Function Display
MHz	Mega Hertz
mm	Millimeter
MOPS	Minimum Operation Performance Standards (RTCA documents)
mrad	milliradian. 1 mrad = 0.001 radian
MS	Mode status
MSL	Minimum Signal Level
MTL	Minimum Trigger Level
MTBF	Mean-Time-Between-Failures
MTR	Military Training Route
MTTF	Mean Time To Failure
MTTR	Mean-Time To Restore
N/A	Not Applicable or No Change
NAC	Navigation Accuracy Category (sub “p” is for position and sub “v” is for velocity)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NIC	Navigation Integrity Category
NIC_{BARO}	Barometric Altitude Integrity code
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium - National Aerospace Laboratory in the Netherlands
NM	Nautical Mile
NMAC	Near Mid Air Collision
NMPH	Nautical Miles Per Hour
NOTAM	NOTice to AirMen
NPA	Non-Precision Approach
NSE	Navigation System Error
NTSB	National Transportation Safety Board
NUC	Navigation Uncertainty Category
O/S	Own Ship

OC	On Condition
OH	Operational Hazard
OHA	Operational Hazard Assessment
OPA	Operational Performance Assessment
OSA	Operational Safety Analysis
OSED	Operational Services and Environment Description
OTW	Out-the-Window
PA	Prevention Advisory
PAPI	Precision Approach Path Indicator
PAZ	Protected Airspace Zone
PF	Pilot Flying
PFD	Primary Flight Display
PIREP	Pilot Report
PNF	Pilot Not Flying
PO-ASAS	Principles of Operation for the Uses of ASAS (See the entry in Appendix B for [PO-ASAS])
PRM	Precision Runway Monitor
PSR	Primary Surveillance Radar
R&D	Research and Development
RA	Resolution Advisory (TCAS II),
rad	radian, an SI metric system derived unit for plane angle
RAIM	Receiver Autonomous Integrity Monitoring
R_C	Radius of Containment
RCP	Required Communications Performance
Rcv	Receive
REQ No.	Requirement Number
RIPS	Runway Incursion Prevention System
RMP	Required Monitoring Performance
RMS	Root Mean Square
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minimum
Rx	receive, receiver
s	second, the SI metric system base unit for time or time interval
SA	Selective Availability
SAE	Society of Automotive Engineers
SAR	Search and Rescue
SARPs	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SC	Special Committee
SDA	System Design Assurance
SF21	Safe Flight 21
SGS	Surface Guidance System
SI	Système International d'Unités (International System of Units not to be confused with the Mode Select Beacon system SI function)
SIL	Source Integrity Level

SIRO	Simultaneous Intersecting Runway Operations
SM	Statute Miles
SMM	Surface Moving Map
SNR	Signal-to-Noise Ratio
SPR	Surveillance Position Reference point
SPS	Standard Positioning Service
SSR	Secondary Surveillance Radar
STP	Surveillance Transmit Processing
SUA	Special Use Airspace
SV	State Vector
SVFR	Special Visual Flight Rules
TA	Traffic Advisory (TCAS II)
TAS	True Airspeed
TAWS	Terrain Awareness and Warning System
TBD	To Be Defined
TC	Trajectory Change (for Trajectory Change report)
TCAS	Traffic Alert and Collision Avoidance System (See ACAS)
TCAS I	TCAS system that does not provide resolution advisories
TCAS II	TCAS system that provides resolution advisories
TCMI	Trajectory Change Management Indicator
TCP	Trajectory Change Point
TCV	Test Criteria Violation
TESIS	Test and Evaluation Surveillance and Information System
TIS	Traffic Information Service
TIS-B	Traffic Information Service – Broadcast
TLAT	Technical Link Assessment Team
TLS	Target Level Safety
TMA	Traffic Management Area
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TOA	Time of Applicability
TORCH	Technical ecOnomical and opeRational assessment of an ATM Concept acHiveable from the year 2005
TQL	Transmit Quality Level
TRACON	Terminal Area CONtrol
TS	Target State (for Target State report)
TSD	Traffic Situation Display
TSE	Total System Error
TTF	Traffic To Follow
TTG	Time to Go
Tx	Transmit
U.S.	United States of America
UAT	Universal Access Transceiver
UHF	Ultra High Frequency: The band of radio frequencies between 300 MHz and 3 GHz, with wavelengths between 1 m and 100 mm.
UMAS	Unmanaged Airspace
UPT	User Preferred Trajectory
USAF	United States Air Force.
UTC	Universal Time, Coordinated, formerly Greenwich Mean Time
Vapp	Final Approach Speed

VDL-4	Very High Frequency Data Link Mode 4
VEPU	Vertical Position Uncertainty
VFOM	Vertical Figure Of Merit
VFR	Visual Flight Rules
VHF	Very High Frequency: The band of radio frequencies between 30 MHz and 300 MHz, with wavelengths between 10 m and 1 m.
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omni-directional Radio
VPL	Vertical Protection Limit
Vref	Reference Landing Velocity
WAAS	Wide Area Augmentation System
WCB	Worst Case Blunder
WG	Working Group
WGS-84	World Geodetic System - 1984
xmit	transmit, transmitter

A.2 Definitions of Terms

The following are definitions of terms used in this document. Square brackets, e.g., [RTCA DO-242A], refer to entries in the bibliography in Appendix B.

Accuracy – A measure of the difference between the A/V position reported in the ADS-B message field as compared to the true position. Accuracy is usually defined in statistical terms of either: 1) a mean (bias) and a variation about the mean as defined by the standard deviation (sigma) or a root mean square (rms) value from the mean. The values given in this document are in terms of the two sigma variation from an assumed zero mean error.

Active Waypoint – A waypoint to or from which navigational guidance is being provided. For a parallel offset, the active waypoint may or may not be at the same geographical position as the parent waypoint. When not in the parallel offset mode (operating on the parent route), the active and parent waypoints are at the same geographical position.

ADS-B Aircraft Subsystem – The set of avionics, including antenna(s), which perform ADS-B functionality in an aircraft. Several Equipage Classes of ADS B Aircraft Subsystems are specified, with different performance capabilities.

ADS-B Application – An operational application, external to the ADS B System, which requires ADS B Reports as input.

ADS-B Participant – An ADS-B network member that is a supplier of information to the local ADS-B subsystem and/or a user of information output by the transmitting subsystem. This does not include the ADS-B subsystem itself.

ADS-B Participant Subsystem – An entity which can either receive ADS B messages and recover ADS-B Reports (Receiving Subsystem) and/or generate and transmit ADS-B messages (Transmitting Subsystem).

ADS-B Message – An ADS-B Message is a block of formatted data which conveys information used in the development of ADS B reports in accordance with the properties of the ADS B Data Link.

ADS-B Message Assembly Function – Takes as inputs ADS B source data. Prepares contents of, but not envelope for, ADS-B messages and delivers same to the ADS B Message Exchange Function.

ADS-B Message Exchange Function – Takes as inputs the message data to be transmitted, packages the data within implementation specific envelopes to form messages to be transmitted. Messages are transmitted and received. Received messages are validated and accepted and the implementation specific envelope is discarded. The received message data is provided to the ADS-B Report Assembly Function. Some subsystems transmit only; some subsystems receive only. The message exchange function includes the transmit and receive antennas along with any diversity mechanisms.

ADS-B Position Reference Point – The ADS-B position reference point is the position on an A/V that is broadcast in ADS-B messages as the nominal position of that A/V. For aircraft and ground vehicles, this position is the center of a rectangle that is aligned parallel to the A/V’s heading and has length and width equal to the longest possible length and width for an aircraft with the same length and width codes as that element transmits while on the surface. The ADS-B position reference point is located such that the actual extent of the A/V is contained entirely that rectangle centered on the ADS-B position reference point.

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ADS-B Report – ADS-B Reports are specific information provided by the ADS B receive subsystem to external applications. Reports contain identification, state vector, and status/intent information. Elements of the ADS B Report that are used and the frequency with which they must be updated will vary by application. The portions of an ADS B Report that are provided will vary by the capabilities of the transmitting participant.

ADS-B Report Assembly Function – Takes as inputs the received message data provided from the ADS-B Message Exchange Function. Develops ADS B reports using the received message data to provide an ADS-B report as output to an ADS-B application.

ADS-B Source Data – The qualified source data provided to the ADS B Message Generation Function and ultimately used in the development of ADS B Reports.

ADS-B System – A collection of ADS-B subsystems wherein ADS B messages are broadcast and received by appropriately equipped Participant Subsystems. Capabilities of Participant Subsystems will vary based upon class of equipage.

Aeronautical Radionavigation Service – A radionavigation service intended for the benefit and safe operation of aircraft.

Airborne Collision – This occurs when two aircraft that are in flight come into contact. The word "collision" is not an antonym of the word "separation."

Airborne Separation Assistance System (ASAS) – An aircraft system based on airborne surveillance that provides assistance to the flight crew supporting the separation of their aircraft from other aircraft.

Airborne Separation Assistance Application – A set of operational procedures for controllers and flight crews that makes use of an Airborne Separation Assistance System to meet a defined operational goal.**Airborne Surveillance and Separation Assurance Processing (ASSAP) –** ASSAP is the processing subsystem that accepts surveillance inputs, (e.g., ADS-B reports), performs surveillance processing to provide reports and tracks, and performs application-specific processing. Surveillance reports, tracks, and any application-specific alerts or guidance are output by ASSAP to the CDTI function. ASSAP surveillance processing consists of track processing and correlation of ADS-B, TIS-B, ADS-R, and TCAS reports).

Airborne Traffic Situational Awareness applications (ATSA applications) – These applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changes in separation tasks are required for these applications." [PO-ASAS, p.1]**Aircraft Surveillance Applications (ASA) –** Airborne and surface functions that use ADS-B data and on board processing to be displayed to the flight crew to enhance their situational awareness, identify potential conflicts and/or collisions, and in the future to change the own-ship's spacing from other aircraft.

Aircraft/Vehicle (A/V) – Either: 1) a machine or service capable of atmospheric flight, or 2) a vehicle on the airport surface movement area.

A/V Address – The term "address" is used to indicate the information field in an ADS-B Message that identifies the A/V that issued the message. The address provides a convenient means by which ADS-B receiving units, or end applications, can sort messages received from multiple issuing units.

Air/Ground State – An internal state in the transmitting ADS-B subsystem that affects which SV report elements are to be broadcast, but which is not required to be broadcast in ADS-B messages from that participant.

Air Mass Data – Air mass data includes barometric altitude, air speed, and heading.

Air Referenced Velocity (AVR) Report

Alert – A general term that applies to all advisories, cautions, and warning information, can include visual, aural, tactile, or other attention-getting methods.

Alert Zone – In the Free Flight environment, each aircraft will be surrounded by two zones, a protected zone and an alert zone. The alert zone is used to indicate a condition where intervention may be necessary. The size of the alert zone is determined by aircraft speed, performance, and by CNS/ATM capabilities.

Applications – Specific use of systems that address particular user requirements. For the case of ADS-B, applications are defined in terms of specific operational scenarios.

Approach Spacing for Instrument Approaches (ASIA) – An application, described in Appendix I, in which, when approaching an airport, the flight crew uses the CDTI display to help them control their own-ship distance behind the preceding aircraft.

ASAS application – A set of operational procedures for controllers and flight crews that makes use of the capabilities of ASAS to meet a clearly defined operational goal. [PO-ASAS, p. 1]

Assured Collision Avoidance Distance (ACAD) – The minimum assured vertical and horizontal distances allowed between aircraft geometric centers. If this distance is violated, a collision or dangerously close spacing will occur. These distances are fixed numbers calculated by risk modeling.

Assured Normal Separation Distance (ANSD) – The normal minimum assured vertical and horizontal distances allowed between aircraft geometric centers. These distances are entered by the pilot or set by the system. Initially the ANSD will be based on current separation standards (and will be larger than the ACAD). In the long term, collision risk modeling will set the ANSD. Ultimately the ANSD may be reduced toward the value of the ACAD.

Automatic Dependent Surveillance-Broadcast (ADS-B) – ADS-B is a function on an aircraft or surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is automatic because no external stimulus is required to elicit a transmission; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users.

Automatic Dependent Surveillance – Rebroadcast (ADS-R) – ADS-R is a “gateway” function on ground systems that rebroadcasts an ADS-B-like message from traffic (including surface vehicles) that utilizes one broadcast link (RF medium) to users such as airborne receive systems that utilize a different ADS-B broadcast link.

Availability – Availability is an indication of the ability of a system or subsystem to provide usable service. Availability is expressed in terms of the probability of the system or subsystem being available at the beginning of an intended operation.

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Background Application – An application that applies to all surveilled traffic of operational interest. One or more background applications may be in use in some or all airspace (or on the ground), but without flight crew input or automated input to select specific traffic. Background applications include: Enhanced Visual Acquisition (EV Acq), Conflict Detection (CD), Airborne Conflict Management (ACM), Airport Surface Situational Awareness (ASSA), and Final Approach and Runway Occupancy Awareness (FAROA).

Barometric altitude – Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum plane, measured by a pressure (barometric) altimeter.

Barometric altitude error – For a given true barometric pressure, P0, the error is the difference between the transmitted pressure altitude and the altitude determined using a standard temperature and pressure model with P0.

Barometric Altitude Integrity Code (NIC_{BARO}) – NIC_{BARO} is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude.

Call Sign – The term "aircraft call sign" means the radiotelephony call sign assigned to an aircraft for voice communications purposes. (This term is sometimes used interchangeably with "flight identification" or "flight ID"). For general aviation aircraft, the aircraft call sign is normally its national registration number; for airline and commuter aircraft, it is usually comprised of the company name and flight number (and therefore not linked to a particular airframe); and for the military, it usually consists of numbers and code words with special significance for the operation being conducted.

Capability Class Codes – Codes that indicate the capability of a participant to support engagement in various operations.

Closest Point of Approach (CPA) – The minimum horizontal distance between two aircraft during a close proximity encounter, also know as miss distance.

Coast Interval – The maximum time interval allowed for maintaining an ADS-B report when no messages supporting that report are received. Requirements for coast interval are typically specified in terms of 99% probability of reception at a given range.

Cockpit Display of Traffic Information (CDTI) – The pilot interface portion of a surveillance system. This interface includes the traffic display and all the controls that interact with such a display. The CDTI receives position information of traffic and own-ship from the airborne surveillance and separation assurance processing (ASSAP) function. The ASSAP receives such information from the surveillance sensors and own-ship position sensors.

Cockpit Display of Traffic Information (CDTI) Display – A single CDTI display format. A physical display screen may have more than one instance of a CDTI Display on it. For example, a display with a split screen that has a Traffic Display on one half of the screen and a list of targets on the other half has two instances of CDTI Displays.

Collision Avoidance – An unplanned maneuver to avoid a collision.

Collision Avoidance Zone (CAZ) – Zone used by the system to predict a collision or dangerously close spacing. The CAZ is defined by the sum of Assured Collision Avoidance Distance (ACAD) and position uncertainties.

Collision Avoidance Zone (CAZ) Alert – An alert that notifies aircraft crew that a CAZ penetration will occur if immediate action is not taken. Aggressive avoidance action is essential.

Compensated Latency – That part of Total Latency that is compensated for to a new time of applicability, valid at an interface 'Y', through data extrapolation aiming at reducing the effects of latency. Compensated Latency may change for each new received/processed track. The related position error is the product of Compensated Latency and the accuracy error of the A/V velocity used for the extrapolation. (see Figure 3-15)

Conflict – A predicted violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based. This document only addresses aircraft traffic. See *Traffic Conflict.*

Conflict Detection – The discovery of a conflict as a result of a computation and comparison of the predicted flight paths of two or more aircraft for the purpose of determining conflicts (ICAO).

Conflict Detection Zone (CDZ) Alert – An alert issued at the specified look ahead time prior to CDZ penetration if timely action is not taken. Timely avoidance action is required.

Conflict Detection Zone (CDZ) Penetration Notification – Notification to the crew when the measured separation is less than the specified CDZ.

Conflict Detection Zone (CDZ) – Zone used by the system to detect conflicts. The CDZ is defined by the sum of ANSD, position uncertainties, and trajectory uncertainties. By attempting to maintain a measured separation no smaller than the CDZ, the system assures that the actual separation is no smaller than the ANSD.

Conflict Management – Process of detecting and resolving conflicts.

Conflict Prevention – The act of informing the flight crew of flight path changes that will create conflicts.

Conflict Probe – The flight paths are projected to determine if the minimum required separation will be violated. If the minima are not [projected to be] violated, a brief preventive instruction will be issued to maintain separation. If the projection shows the minimum required separation will be violated, the conflict resolution software suggests an appropriate maneuver.

Conflict Resolution – A maneuver that removes all predicted conflicts over a specified "look-ahead" horizon. (ICAO - The determination of alternative flight paths, which would be free from conflicts and the selection of one of these flight paths for use.)

Conformal – A desirable property of map projections. A map projection (a function that associate points on the surface of an ellipsoid or sphere representing the earth to points on a flat surface such as the CDTI display) is said to be *conformal* if the angle between any two curves on the first surface is preserved in magnitude and sense by the angle between the corresponding curves on the other surface.

Continuity – The continuity of a system is the ability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation and was predicted to operate throughout the operation.

Cooperative Separation – This concept envisions a transfer of responsibility for aircraft separation from ground based systems to the air-crew of appropriately equipped aircraft, for a specific separation function such as In-trail merging or separation management of close proximity encounters. It is cooperative in the sense that ground-based ATC is involved in the handover process, and in the sense that all involved aircraft must be appropriately equipped, e.g., with RNAV and ADS-B capability, to perform such functions.

Cooperative Surveillance – Surveillance in which the target assists by cooperatively providing data using on-board equipment.

Correlation – The process of determining that a new measurement belongs to an existing track.

Coupled Application – Coupled applications are those applications that operate only on specifically-chosen (either by the flight crew or automation) traffic. They generally operate only for a specific flight operation. Coupled applications include Enhanced Visual Approach, Approach Spacing for Instrument Approaches, and Independent Closely Spaced Parallel Approaches.

Coupled Target – A coupled target is a target upon which a coupled application is to be conducted.

Covariance – A two dimensional symmetric matrix representing the uncertainty in a track's state. The diagonal entries represent the variance of each state; the off-diagonal terms represent the covariances of the track state.

Cross-link – A cross-link is a special purpose data transmission mechanism for exchanging data between two aircraft—a two-way addressed data link. For example, the TCAS II system uses a cross-link with another TCAS II to coordinate resolution advisories that are generated. A cross-link may also be used to exchange other information that is not of a general broadcast nature, such as intent information.

Data Block – A block of information about a selected target that is displayed somewhere around the edge of the CDTI display, rather than mixed in with the symbols representing traffic targets in the main part of the display.

Data Tag – A block of information about a target that is displayed next to symbol representing that target in the main part of the CDTI display.

Desirable – The capability denoted as *Desirable* is not required to perform the procedure but would increase the utility of the operation.

Display range – The maximum distance from own-ship that is represented on the *CDTI* display. If the *CDTI* display is regarded as a map, then longer display ranges correspond to smaller map scales, and short display ranges correspond to larger map scales.

Domain – Divisions in the current airspace structure that tie separation standards to the surveillance and automation capabilities available in the ground infrastructure. Generally there are four domains: surface, terminal, en route, and oceanic/remote and uncontrolled. For example, terminal airspace, in most cases comprises airspace within 30 miles and 10,000 feet AGL of airports with a terminal automation system and radar capability. Terminal IFR separation standards are normally 3 miles horizontally and 1000 feet vertically.

Enhanced Visual Acquisition (EV Acq) – The enhanced visual acquisition application is an enhancement for the out-the-window visual acquisition of aircraft traffic and potentially ground vehicles. Pilots will use a *CDTI* to supplement and enhance out-the-window visual acquisition. Pilots will continue to visually scan out of the window while including the *CDTI* in their instrument scan,***Note:*** *An extended display range capability of at least 90 NM from own-ship is desirable for the ACM application.*

Estimation – The process of determining a track's state based on new measurement information.

Explicit Coordination – Explicit coordination of resolutions requires that the aircraft involved in a conflict communicate their intentions to each other and (in some strategies) authorize/confirm each other's maneuvers. One example of an explicit coordination technique would be the assignment of a 'master' aircraft, which determines resolutions for other aircraft involved in the conflict. Another is the crosslink used in *ACAS*.

Extended Display Range – Extended display range is the capability of the CDTI to depict traffic at ranges beyond the standard display range maximum of 40 NM.

Note: *An extended display range capability of at least 90 NM from own-ship is desirable for the ACM application.*

Extended Runway Center Line – An extension outwards of the center line of a runway, from one or both ends of that runway.

Extrapolation – The process of predicting a track's state forward in time based on the track's last kinematic state.

Field of View – The *field of view* of a *CDTI* is the geographical region within which the *CDTI* shows *traffic targets*. (Some other documents call this the field of regard.)

Flight Crew – One or more cockpit crew members required for the operation of the aircraft.

Foreground Application – An ASA application that the crew can activate and/or deactivate, the foreground applications is not intended to run full-time or activate automatically without crew interaction.

Garble – Garble is either nonsynchronous, in which reply pulses are received from a transponder being interrogated by some other source (see FRUIT), or synchronous, in which an overlap of reply pulses occurs when two or more transponders reply to the same interrogation.

Generic Conflict – A violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based.

Geometric height – The minimum altitude above or below a plane tangent to the earth's ellipsoid as defined by WGS-84.

Geometric height error – Geometric height error is the error between the true geometric height and the transmitted geometric height.

Geometric Vertical Accuracy (GVA) – The GVA parameter is a quantized 95% bound of the error of the reported geometric altitude, specifically the Height Above the WGS-84 Ellipsoid (HAE).

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This parameter is derived from the Vertical Figure of Merit (VFOM) output by the position source.

GNSS sensor integrity risk – The probability of an undetected failure that results in NSE (navigation system error) that significantly jeopardizes the total system error (TSE) exceeding the containment limit. [DO-247, §5.2.2.1]

Global Positioning System (GPS) – A space-based positioning, velocity and time system composed of space, control and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment consists of five monitor stations, three ground antennas and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

Ground Speed – The magnitude of the horizontal velocity vector (see *velocity*). In these MASPS it is always expressed relative to a frame of reference that is fixed with respect to the earth's surface such as the WGS-84 ellipsoid.

Ground Track Angle – The direction of the horizontal velocity vector (see *velocity*) relative to the ground as noted in Ground Speed.

Hazard Classification – An index into the following table:

Hazard	Class	Acceptable failure rate
1	"Catastrophic" consequences	10^{-9} per flight hour
2	"Hazardous/Severe Major" consequences	10^{-7} per flight hour
3	"Major" consequences	10^{-5} per flight hour
4	"Minor" consequences	10^{-3} per flight hour
5	Inconsequential, no effect	

Hertz (Hz) – A rate where 1 Hz = once per second.

Horizontal Protection Limit (HPL) – The radius of a circle in the horizontal plane (i.e. the plane tangent to the WGS-84 ellipsoid), with its center being the true position, which describes the region which is assured to contain the indicated horizontal position. This computed value is based upon the values provided by the augmentation system.

Horizontal velocity – The horizontal component of velocity relative to a ground reference (see *Velocity)*.

Implicit Coordination – Implicitly coordinated resolutions are assured not to conflict with each other because the responses of each pilot are restricted by common rules. A terrestrial example of an implicit coordination rule is "yield to the vehicle on of conflict based on how the parameters are defined." Criteria can be either geometry based or time-based.

Integrity Containment Risk (ICR) – The per-flight-hour probability that a parameter will exceed its containment bound without being detected and reported within the required time to alert. (See also *Integrity* and *Source Integrity Level*.)

In-Trail Climb – In-trail climb (ITC) procedures enables trailing aircraft to climb to more fuel-efficient or less turbulent altitude.

In-Trail Descent – In-trail descent (ITD) procedures enables trailing aircraft to climb to more fuel-efficient or less turbulent altitude.

Interactive Participants – An ADS-B network member that is a supplier of information to the local ADS-B subsystem and a user of information output by the subsystem. Interactive participants receive messages and assemble reports specified for the respective equipage class.

International Civil Aviation Organization (ICAO) – A United Nations organization that is responsible for developing international standards, recommended practices, and procedures covering a variety of technical fields of aviation.

Latency – Latency is the time incurred between two particular interfaces. Total latency is the delay between the true time of applicability of a measurement and the time that the measurement is reported at a particular interface (the latter minus the former). Components of the total latency are elements of the total latency allocated between different interfaces. Each latency component will be specified by naming the interfaces between which it applies.

Latency Compensation – High accuracy applications may correct for system latency introduced position errors using ADS-B time synchronized position and velocity information.

Latency Compensation Error (formerly referred to as "Uncompensated Latency") – That part of Total Latency that is not compensated and/or under/overcompensated for. The value is usually positive but overcompensation might produce negative values as well. The Latency Compensation Error may change for each new received/processed track. The related position error is the product of Latency Compensation Error and true A/V velocity. (see Figure 3-15)

Low Level Alert – An optional alert issued when CDZ penetration is predicted outside of the CDZ alert boundary.

Minimum Triggering Level (MTL) – The minimum input power level that results in a 90% reply ratio in the Mode A/C format or in the Mode S format if the interrogation signal has all nominal spacings and widths and if the replies are the correct replies assigned to the interrogation format.

Mixed Equipage – An environment where all aircraft do not have the same set of avionics. For example, some aircraft may transmit ADS-B and others may not, which could have implications for ATC and pilots. A mixed equipage environment will exist until all aircraft operating in a system have the same set of avionics.

Nautical mile (NM) – A unit of length used in the fields of air and marine navigation. In this document, a nautical mile is always the international nautical mile of 1852 meters exactly.

Navigation Accuracy Category - Position (NAC_P) – The NAC_P parameter describes the accuracy region about the reported position within which the true position of the surveillance position reference point is assured to lie with a 95% probability at the reported time of applicability.

Navigation Accuracy Category - Velocity (NAC_V) – The NAC_V parameter describes the accuracy about the reported velocity vector within which the true velocity vector is assured to be with a 95% probability at the reported time of applicability.

Navigation Integrity Category (NIC) – NIC describes an integrity containment region about the reported position, within which the true position of the surveillance position reference point is assured to lie at the reported time of applicability.

Navigation sensor availability – An indication of the ability of the guidance function to provide usable service within the specified coverage area, and is defined as the portion of time during which the sensor information is to be used for navigation, during which reliable navigation information is presented to the crew, autopilot, or other system managing the movement of the aircraft.

Navigation sensor availability is specified in terms of the probability of the sensor information being available at the beginning of the intended operation. [RTCA DO-247, §5.2.2.3]

Navigation sensor continuity – The capability of the sensor (comprising all elements generating the signal in space and airborne reception) to perform the guidance function without non-scheduled interruption during the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation sensor continuity risk – The probability that the sensor information will be interrupted and not provide navigation information over the period of the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation System Integrity – This relates to the trust that can be placed in the correctness of the navigation information supplied. Integrity includes the ability to provide timely and valid warnings to the user when the navigation system must not be used for navigation.**Navigation Uncertainty Category (NUC) –** Uncertainty categories for the state vector navigation variables are characterized by a NUC data set provided in the ADS-B sending system. The NUC includes both position and velocity uncertainties. (This term was used in DO-242. DO-242A separated the integrity and accuracy components of NUC into NIC, NAC, and SIL parameters.)

Operational Mode Code – A code used to indicate the current operational mode of transmitting ADS-B participants.

Own-ship – From the perspective of a flight crew, or of the ASSAP and CDTI functions used by that flight crew, the own-ship is the ASA participant (aircraft or vehicle) that carries that flight crew and those ASSAP and CDTI functions.

Passing Maneuvers – Procedures whereby pilots use: 1) onboard display of traffic to identify an aircraft they wish to pass; 2) traffic display and weather radar to establish a clear path for the maneuver; and 3) voice communication with controllers to positively identify traffic to be passed, state intentions and report initiation and completion maneuver.

Persistent Error – A persistent error is an error that occurs regularly. Such an error may be the absence of data or the presentation of data that is false or misleading. An unknown measurement bias may, for example, cause a persistent error.

Positional Uncertainty – Positional uncertainty is a measure of the potential inaccuracy of an aircraft's position-fixing system and, therefore, of ADS-B-based surveillance. Use of the Global Positioning System (GPS) reduces positional inaccuracy to small values, especially when the system is augmented by either space-based or ground-based subsystems. However, use of GPS as the position fixing system for ADS-B cannot be assured, and positional accuracy variations must be take into account in the calculation of CDZ and CAZ. When aircraft are in close proximity and are using the same position-fixing system, they may be experiencing similar degrees of uncertainty. In such a case, accuracy of relative positioning between the two aircraft may be considerably better than the absolute positional accuracy of either. If, in the future, the accuracy of relative positioning can be assured to the required level, it may be possible to take credit for the phenomenon in calculation of separation minima. For example, vertical separation uses this principle by using a common barometric altitude datum that is highly accurate only in relative terms.

Primary Surveillance Radar (PSR) – A radar sensor that listens to the echoes of pulses that it transmits to illuminate aircraft targets. PSR sensors, in contrast to secondary surveillance radar (SSR) sensors, do not depend on the carriage of transponders on board the aircraft targets.

Proximity Alert – An alert to the flight crew that something is within pre-determined proximity limits (e.g., relative range, or relative altitude difference) of own vehicle.

Range reference – The CDTI feature of displaying range rings or other range markings at specified radii from the own-ship symbol.

Received Update Rate – The sustained rate at which periodic ADS-B messages are successfully received, at a specified probability of reception.

Regime – Divisions in the future airspace structure in contrast to the current concept of domains. Based on the European concept the three regimes are:

1. **Managed Airspace (MAS)**
   - Known traffic environment
   - Route network 2D/3D and free routing
   - Separation responsibility on the ground, but may be delegated to the pilots in defined circumstances
2. **Free Flight Airspace (FFAS)** – FFAS is also known as Autonomous Airspace.
   - Known traffic environment
3. **Autonomous operations Separation responsibility in the air Unmanaged Airspace (UMAS**)
   - Unknown traffic environment
   - See [Rules of the air].

Registration – The process of aligning measurements from different sensors by removing systematic biases.

Required – The capability denoted as Required is necessary to perform the desired application.

Resolution – The smallest increment reported in an ADS-B message field. The representation of the least significant bit in an ADS-B message field.

Safe Flight 21 – The Safe Flight 21 Program was a joint government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures. The program is demonstrating nine operational enhancements selected by RTCA, and providing the FAA and industry with valuable information needed to make decisions about implementing applications that have potential for significant safety, efficiency, and capacity benefits.

Seamless – A "chock-to-chock" continuous and common view of the surveillance situation from the perspective of all users.

Secondary Surveillance Radar (SSR) – A radar sensor that listens to replies sent by transponders carried on board airborne targets. SSR sensors, in contrast to *primary surveillance radar* (PSR*)* sensors, require the aircraft under surveillance to carry a *transponder*.

Selected Target – A selected target is a target for which additional information is requested by the flight crew.

Sensor – A measurement device. An air data sensor measures atmospheric pressure and temperature, to estimate pressure altitude, and pressure altitude rate, airspeed, etc. A *primary surveillance radar*

(PSR) sensor measures its antenna direction and the times of returns of echoes of pulses that it transmits to determine the ranges and bearings of airborne targets. A *secondary surveillance radar* (SSR) sensor measures its antenna direction and the times of returns of replies from airborne transponders to estimate the ranges and bearings of airborne targets carrying those transponders.

Separation – Requirements or Separation Standards – The minimum distance between aircraft/vehicles allowed by regulations. Spacing requirements vary by various factors, such as radar coverage (none, single, composite), flight regime (terminal, en route, oceanic), and flight rules (instrument or visual).

Separation Violation – Violation of appropriate separation requirements.

Source Integrity Level (SIL) – The Source Integrity Level (SIL) defines the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-in-Space, if a Signal-in-Space is used by the position source. The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the System Design Assurance (SDA) parameter.

Spacing – A distance maintained from another aircraft for specific operations.

State (vector) – An aircraft's current horizontal position, vertical position, horizontal velocity, vertical velocity, turn indication, and navigational accuracy and integrity.

Station-keeping – Station-keeping provides the capability for a pilot to maintain an aircraft's position relative to the designated aircraft. For example, an aircraft taxiing behind another aircraft can be cleared to follow and maintain separation on a lead aircraft. Station-keeping can be used to maintain a given (or variable) separation. An aircraft that is equipped with an ADS-B receiver could be cleared to follow an FMS or GNSS equipped aircraft on a GNSS/FMS/RNP approach to an airport. An aircraft doing station-keeping would be required to have, as a minimum, some type of CDTI.

Subsystem Availability Risk – The probability, per flight hour, that an ASA subsystem is not available, that is, that it is not meeting its functional and performance requirements.

was operating at the start of the hour or operation, that the subsystem will continue to be available through the remainder of the hour or operation.

System Design Assurance (SDA) – Defines the failure condition that the position transmission chain is designed to support. The position transmission chain includes the ADS-B transmission equipment, ADS-B processing equipment, position source, and any other equipment that processes the position data and position quality metrics that will be transmitted. The supported failure condition will indicate the probability of a position transmission chain fault causing false or misleading information to be transmitted. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1A, AC 23-1309-1C, and AC 29-2C. All relevant systems attributes should be considered including software and complex hardware in accordance with RTCA DO-178B (EUROCAE ED-12B) or RTCA DO-254 (EUROCAE ED-80).

Target Selection – Manual process of flight crew selecting a target.

Target – Traffic of particular interest to the flight crew.

Target Altitude – The aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude.

Target Heading – The aircraft's intended heading after turn completion or its current intended heading if in straight flight.

Target State Report (TS Report) – An on-condition report specifying short-term intent information.

Target Track Angle – The aircraft's intended track angle over the ground after turn completion or its current intended track angle if in straight flight.

TCAS Alert Status – The status of the TCAS track, if applicable, from the TCAS system. The four states are: Resolution Advisory (RA), Traffic Advisory (TA), Proximate, and other.

TCAS Potential Threat – A traffic target, detected by TCAS equipment on board the own-ship, that has passed the Potential Threat classification criteria for a TCAS TA (traffic advisory) and does not meet the Threat Classification criteria for a TCAS RA (resolution advisory). ([DO-185A, §1.8) (If the ASAS own-ship CDTI display is also used as a TCAS TA display, then information about TCAS potential threats will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS Proximate Traffic – A traffic target, detected by TCAS equipment on board the own-ship, that is within 1200 feet and 6 NM of the own-ship. ([DO-185A]. §1.8) (If the ASAS own-ship CDTI display is also used as a TCAS TA display, then information about TCAS proximate traffic targets will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS-Only Target – A traffic target about which TCAS has provided surveillance information, but which the ASSAP function has not correlated with targets from other surveillance sources (such as ADS-B, TIS, or TIS-B).

Time of Applicability – The time that a particular measurement or parameter is (or was) relevant. The Time of Applicability at an interface 'Y' (see Figure 3-15), is the TOA as valid at a lower interface 'X' plus the amount of Compensated Latency applied to and valid at an upper interface 'Y'. Therefore, the Time of Applicability uncertainty is the (sum of) Latency Compensation Errors up to interface 'Y'. Regarding the notion of a "common" TOA, it is noted that the time of applicability uncertainty will generally vary between tracks.

TIS-B – Traffic Information Services – Broadcast (TIS-B) is a function on ground systems that broadcasts an ADS-B-like message that includes current position information of aircraft/vehicles within its surveillance volume. The aircraft/vehicle position information may be measured by a ground surveillance system such as a secondary surveillance radar (SSR) or a multilateration system.

Total Latency – The total time between the availability of information at a lower interface 'X' to the time of completion of information transfer at an upper interface 'Y'. Total Latency is the sum of Compensated Latency and Latency Compensation Error and is expressed as a single upper value. The related position error is a function of Total Latency and velocity uncertainty. (see Figure 3-15)

Track – A sequence of time-tagged measurements and state information relating to a particular aircraft or vehicle. The track may be a simple list file of A/V position and time data extrapolated to a common time for processing and display, or may include track estimation and Kalman filtering. (1) A sequence of reports from the ASSAP function that all pertain to the same *traffic target*. (2) Within the ASSAP function, a sequence of estimates of traffic target state that all pertain to the same traffic target.

Track angle – See *ground track angle*.

Track State – The basic kinematic variables that define the state of the aircraft or vehicle of a track, e.g., position, velocity, acceleration.

Traffic – All aircraft/vehicles that are within the operational vicinity of own-ship.

Traffic Conflict – Predicted converging of aircraft in space and time, which constitutes a violation of a given set of separation minima. (ICAO).

Traffic Display – The Traffic Display is a graphical plan-view (top down) traffic display. The Traffic Display may be a stand-alone display or displays (dedicated display(s)) or the CDTI information may be present on an existing display(s) (e.g., multi-function display) or an EFB.

Traffic Display Criteria (TDC) – The surveillance range of ASA will frequently include more traffic than is of interest to the flight crew. Displaying too many traffic elements on the Traffic Display may result in clutter, and compromise the intended function of the CDTI. To determine the traffic of interest to the flight crew, a set of TDC is used to filter the traffic. Criteria generally include range and altitude. Additional criteria may also be used. The flight crew may change the TDC.

Traffic Information Service – Broadcast – A surveillance service that broadcasts traffic information derived from one or more ground surveillance sources to suitably equipped aircraft or surface vehicles, with the intention of supporting ASA applications.

Traffic Situation Display (TSD) – A TSD is a cockpit device that provides graphical information on proximate traffic as well as having a processing capability that identifies potential conflicts with other traffic or obstacles. The TSD may also have the capability to provide conflict resolutions.

Traffic symbol – A depiction on the CDTI display of an aircraft or vehicle other than the *own-ship*.

Traffic target – This is an aircraft or vehicle under surveillance. In the context of the ASA subsystems at a receiving ASA participant, traffic targets are aircraft or vehicles about which information is being provided (by ADS-B, TIS-B, TCAS, etc.) to the ASSAP.

Transmission Rate – The sustained rate at which periodic ADS-B messages are transmitted.

Transponder – A piece of equipment carried on board an aircraft to support the surveillance of that aircraft by *secondary surveillance radar* sensors. A transponder receives on the 1030 MHz and replies on the 1090 MHz downlink frequency.

Trajectory Uncertainty – Trajectory uncertainty is a measure of predictability of the future trajectory of each aircraft. There are a number of factors involved in trajectory predictability. These include knowledge of a valid future trajectory, capability of the aircraft to adhere to that trajectory, system availability (e.g., ability to maintain its intended trajectory with a system failure in a non redundant system versus a triple redundant system), and others.

Uncompensated Latency – see “Latency Compensation Error.”

Update Interval – The time interval between successful message receipt with a given probability of successful reception at a specified range. (Nominal Update Interval is considered 95% probability of successful reception at a specified range.)

Update Rate – The reciprocal of update interval (e.g. if the update interval is 5 s, the update rate = 1/5 ~ 0.20 Hz for the example above).

User-Preferred Trajectories (UPT) – A series of one or more waypoints that the crew has determined to best satisfy their requirements.

Velocity – The rate of change of position. Horizontal velocity is the horizontal component of velocity and vertical velocity is the vertical component of velocity. In these MASPS, velocity is always expressed relative to a frame of reference, such as the WGS-84 ellipsoid**Vref –** The reference landing air speed for an aircraft. It is weight dependent. Flight crews may vary their actual landing speed based on winds, etc.

ADS-B IN Application Reference Matrix

ATSSA MASPS Reqmts Details ?	Proposed ATSSA MASPS Name	ATSSA MASPS Category (Tables 2-5 & 2-7)	DO-289 MASPS Name	DO-317A MOPS Name	TSO C-195 Name	Requirements Focus Group Name (SPR)	AIWP 2.0 Name	AIWP Category
Yes (§4.1)	Enhanced Visual Acquisition (EVAcq) (Part 23 only)	SA Application		Enhanced Visual Acquisition (EVAcq)			(App 1) Traffic Situation Awareness - Basic	Situational Awareness
Yes (§4.1)	Basic Airborne Situational Awareness (AIRB)	SA Application	Enhanced Visual Acquisition (EVAcq)	Basic Airborne Situational Awareness (AIRB)	Airborne	Enhanced traffic situational awareness during flight operations (ATSA-AIRB) [DO-319]	(App 1) Traffic Situation Awareness - Basic	Situational Awareness
Yes (§4.2)	Visual Separation on Approach (VSA)	SA Application	Enhanced Visual Approach (EVApp)	Visual Separation on Approach (VSA)	Enhanced Visual Approach	Enhanced visual separation on approach (ATSA-VSA) [DO-314]	(App 2) Traffic Situation Awareness for Visual Approach	Situational Awareness
Yes (§4.3)	Basic Surface Situational Awarenenss (SURF)	SA Application	Airport Surface Situational Awareness (ASSA) / Final Approach Runway Occupancy Awareness (FAROA)	Basic Surface Situational Awarenenss (SURF)	Surface (Runways & Taxiways)	Enhanced traffic situational awareness on the airport surface (ATSA-SURF) [DO-322]	(App 3) Airport Traffic Situational Awareness	Situational Awareness
Future (§4.6)	Airport Traffic Situational Awareness with Indications and Alerts (SURF - IA)	Enhanced SA Application				Enhanced traffic situational awareness on the airport surface with indications and alerts (SURF IA) [DO-323]	(App 4) Airport Traffic Situational Awareness with Indications and Alerts	Situational Awareness with Alerting
Yes (§4.4)	Oceanic In-Trail Procedures (ITP)	Enhanced SA Application				In-Trail Procedures in Oceanic AIrspace (ATSA-ITP) [DO-312]	(App 5) Oceanic In-Trail Procedures (ITP)	Uncategorized

ATSSA MASPS Reqmts Details ?	Proposed ATSSA MASPS Name	ATSSA MASPS Category (Tables 2-5 & 2-7)	DO-289 MASPS Name	DO-317A MOPS Name	TSO C-195 Name	Requirements Focus Group Name (SPR)	AIWP 2.0 Name	AIWP Category
Future (§4.6)	Flight Deck Based Interval Management - Spacing (FIM-S)	Spacing Application				Airborne Spacing - Flight Deck Interval Management - Spacing (ASPA-FIM) [DO-328]	(App 6) Flight Deck Based Interval Management - Spacing (FIM-S)	Airborne Spacing
Future (§4.6)	Traffic Situation Awareness with Alerts (TSAA)	(not addressed) Enhanced SA Application					(App 7) Traffic Situation Awareness with Alerts (TSAA)	Situational Awareness with Alerting
None	Flight-Deck Based Interval Management-with Delegated Separation (FIM-DS) - future rev of 3XX	Delegated Separation	Approach Spacing for Instrument Approaches (ASIA)				(App 8) Flight-Deck Based Interval Management-with Delegated Separation (FIM-DS)	Delegated Separation
None		Delegated Separation					(App 9) Independent Closely Spaced Routes (ICSR)	Delegated Separation
None		Delegated Separation	Independent Closely Spaced Parallel Approaches (ICSPA)				(App 10) Paired Closely Spaced Parallel Approaches	Delegated Separation
None		Delegated Separation					(App 11) Independent Closely Spaced Parallel Approaches	Delegated Separation
None		Delegated Separation					(App 12) Delegated Separation-Crossing	Delegated Separation
None		Delegated Separation					(App 13) Delegated Separation-Passing	Delegated Separation

ATSSA MASPS Reqmts Details ?	**Proposed ATSSA MASPS Name**	**ATSSA MASPS Category (Tables 2-5 & 2-7)**	**DO-289 MASPS Name**	**DO-317A MOPS Name**	**TSO C-195 Name**	**Requirements Focus Group Name (SPR)**	**AIWP 2.0 Name**	**AIWP Category**
None		Delegated Separation					(App 14) Flight Deck Interval Management - Delegated Separation with Wake Risk Management	Delegated Separation
None		not addressed	Airborne Conflict Management (ACM)				(App 15) ADS-B Integrated Collision Avoidance	Hazard Avoidance
None		Self Separation					(App 16) Flow Corridors	Self Seaparation
None		Self Separation					(App 17) Self Separation	Self Separation

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Appendix B
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Appendix C
Derivation of Link Quality Requirements for Future Applications

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C Derivation of Link Quality Requirements for Future Applications

C.1 Background

C.2 Link – Physical Parameters

There are several key physical parameters of a surveillance link which will either allow that link to support or limit its utilization for future applications. Among them are: RF range coverage, RF coverage versus altitude and effective total latency or update rate.

C.2.1 RF Range Coverage

The current situational awareness applications do not have minimum RF coverage requirements, by range. In the future as ADS-B In applications are assigned a greater level of criticality and integrity it may be necessary to assign a minimum RF range coverage requirement (in NM, i.e., equipage Classes) to the links that support each application. The major factors affecting the free space RF range are the effective RF transmitted power, the path loss for that frequency or frequencies over the minimum required distance, and the receive system minimum sensitivity threshold. The co-channel interference in congested airspace may reduce the free space RF range of an equipage class.

C.2.2 RF Coverage versus Altitude

The current situational awareness applications do not have minimum RF coverage requirements, by altitude. As for range, future higher criticality applications may have minimum requirements for RF coverage over a required altitude band. Examples of this would be: (a) coverage down to touchdown for an approach application such as CEDS, or: (b) coverage over the active airport surface movement area for a surface CDTI application such as SURF IA. These requirements could apply to both the direct path (air vehicle to air vehicle) as well as to the air – ground path if either TIS-B and/or ADS-R data would be required for the application. Several proof of concept demonstrations for surface applications have shown that careful attention must be paid to the expected RF performance on the surface. Factors such as ground multipath and line-of-sight blockage must be considered.

C.2.3 Receive Update Interval

The receive update interval is not exceeded 95% of the time for all of the transmitted messages to be received and decoded. Factors influencing this include RF interference, multipath, fading and jamming. If a surveillance message is transmitted every **X** seconds but only 75% of the transmitted messages are successfully received and decoded; it will take multiple transmissions for the update interval to be achieved. Thus, the update interval for that message will be considerably longer than the baseline transmit interval of **X** seconds.

C.3 Link – Performance Quality Parameters

C.3.1 Position Accuracy

The maximum accuracy of a broadcast position data system is limited by the resolution of the position data fields. Currently in the 1090ES broadcast link the resolution of the Airborne Position Message is around 5 meters at the worst case locations. There is a NAC_P category of 11 which requires 95% position accuracy of ±3 meters – this position accuracy quality metric could not be applied to the current 1090ES airborne targets. While no airborne applications have applied a NAC_P=11 requirement yet, a surface application SPR does contain this requirement. (SURF IA/DO-323) The current resolution of the 1090ES surface position messages is around 1.2 meters at the worst case locations.

C.3.2 Position Integrity

Refer to Section C.3.7 for a general discussion on timely data updates which includes the position integrity metrics NIC and SIL.

C.3.3 Velocity Accuracy

The fundamental limit for the accuracy of broadcast velocity data is the resolution of the velocity data fields. Developers of future applications utilizing the current ADS-B Message formats should perform a comparison between the quality metrics applied and the resolution of each message element that those metrics are applied against. There are some combinations of message data types and horizontal velocity quality metrics that are not compatible. For example, in the 1090ES link, the application of a NAC_V = 4 (Velocity accuracy < 0.3 m/s) requirement to the Airborne Velocity Message (Register 09_{16}) Subtypes 1 or 3 (subsonic), which has a minimum resolution of only 1 knot (~0.5 m/s). Another 1090ES example would be the application of a NAC_V = 3 (Velocity accuracy < 1 m/s) or NAC_V = 4 requirement to the Airborne Velocity Message Subtypes 2 or 4 (supersonic), which have a minimum resolution of 4 knots (~2 m/s).

C.3.4 Altitude Accuracy

The fundamental limit for the accuracy of broadcast altitude data is the resolution of the altitude data fields. Currently there are assumed accuracy bounds on the Barometric Pressure derived altitude data and a separate accuracy parameter (GVA) for GNSS derived geometric altitude data.

C.3.5 Vertical Rate Accuracy

The fundamental limit for the accuracy of broadcast vertical rate data is the resolution of the vertical rate data fields. Currently there are no published requirements for vertical rate accuracy in the existing applications. In the current data link standards there are no defined vertical rate accuracy fields in the ADS-B Version 2 standards.

C.3.6 System Design Assurance (SDA)

The error checking that is inherent in each surveillance link's standard (or the lack thereof) is an important factor in the highest SDA or System Hazard Level that that link can support. For example, a single bit parity checking method such as that currently employed by existing ARINC 429 airborne data systems may not support as high of level of system hazard level as a cyclic redundancy check (CRC) implementation.

Also the system architecture is a major factor in determining what level of SDA in the transmit system and Hazard Level in the receiving system can be supported. In general redundant multichannel systems or a single channel system with a parallel full time monitor channel can support a higher system hazard level function than a single channel system is able to support.

C.3.7 Timely Data Updates

The ability of each link to provide timely data updates of not only state data such as position/velocity/altitude but also the associated quality metrics for this state data must be evaluated and coordinated together. For example, it may be of little benefit to future applications if the state data updates are transmitted twice per second but the quality metrics only reflect a change in the status of that data for a much longer period. This would be of most importance for situations where one or more targets went from transmitting data compliant to an application's requirements to transmitting non-compliant data for that application.

C.3.8 Other Update Interval Considerations

Another aspect of timely data updates that must be evaluated is related to the proposed ASA subsystem mitigation techniques for surface applications. This is for scenarios where the broadcast position accuracy (NAC_P) and velocity accuracy (NAC_V) from existing aircraft that do not meet the surface applications' requirements. For example, they may require observation of multiple position reports in order to develop an independent assessment of the target's real time velocity accuracy as opposed to using the target's broadcast NAC_V value. However there is also a requirement for the ASSAP function to deliver real time (low latency) data to the application processing on each target's quality metrics. Thus, only a finite amount of observation and averaging can be performed within the allowable ASSAP latency window.

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Appendix D
Receive Antenna Coverage Constraints

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D Receive Antenna Coverage Constraints

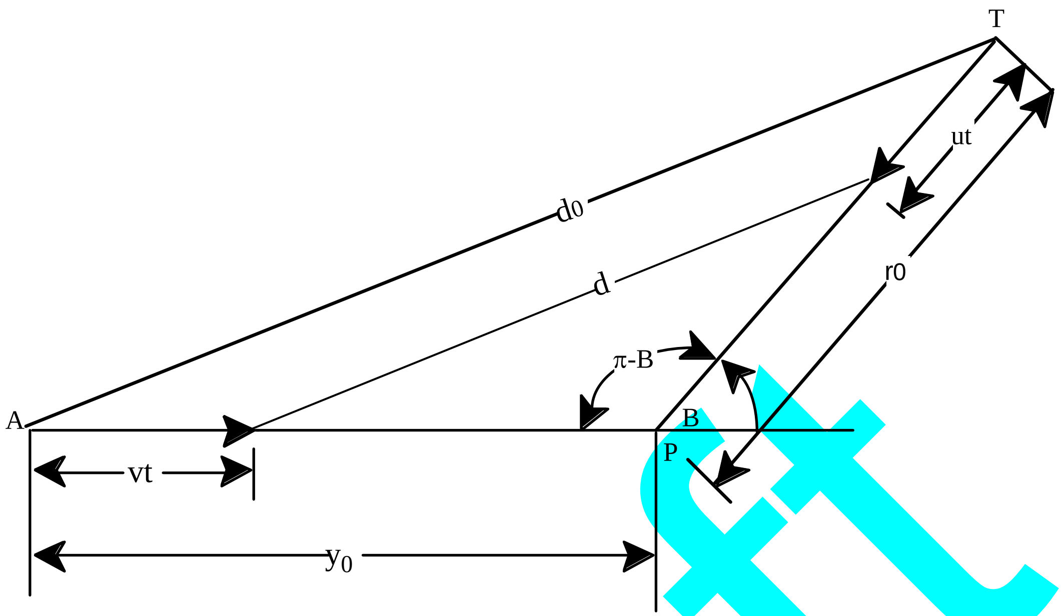
D.1 Introduction

Use of ADS-B broadcasts for ground ATC cooperative surveillance requires omnidirectional aircraft transmit antenna patterns since aircraft must be seen at any azimuthal orientation by the ground site at the maximum service range. If no ground ADS-B uplink functions are implemented however, the ADS-B aircraft receive service is restricted to reception of broadcasts from other aircraft. In this case, since closure rates are higher for head-to-head aircraft encounters, a longer coverage range (i.e., higher receive antenna gain) may be desired in the forward direction. If a single receive antenna is used (or if a pair of receive antennas are used in diversity configurations) some coverage is still required in the rearward direction to cover overtaking encounters. The following treatment identifies a basic limitation on how high the receive gain can be in the forward direction while providing adequate coverage at other aspect angles. Since an altitude difference of 6000 ft at a range of 60 NM corresponds to an elevation angle of one degree, the geometry here is considered to be two-dimensional only.

D.2 Constant Alert Time Analysis

Several criteria may be used to examine air-to-air receive coverage requirements when all aircraft transmit with the same omnidirectional gain, G_O. Figure D-1 shows own aircraft, A, headed along the y-axis at a speed, *v*, with a potential threat aircraft, T, moving at a speed, *u*, on a radial track intercepting the A projected track at y_O at an angle, B. The separation between aircraft as a function of time is d. Figure D-1 also summarizes the relationships defining d and Δd/Δt, the rate of change of this separation range.

Level A3 ADS-B systems were originally designed to support deconfliction applications and specified an acquisition range for an encounter geometry with a minimum alert time requirement of 4.5 minutes (DO-242A, Table 2-8) depending on the encounter angle B as shown in Figure D-1. The worst case geometry is a head-on encounter with B=0° and both aircraft traveling at 600 kts, i.e., $u = v = 600$ kts. In this case the closure rate Δd/Δt is 20 NM/min and the acquisition range in the forward direction is R = 20 NM/min * 4.5 min = 90 NM. For a crossing encounter with B=90° and both aircraft traveling 600 kts we have $d / \sqrt{2} = y = r$ and the closure rate is $\Delta d/\Delta t = 10 * \sqrt{2} \sim 14.14$ NM/min. The acquisition range for this geometry is thus R = 14.14 NM/min * 4.5 min ~ 64 NM. In the rear direction B= 180°, the worst case geometry for an overtake is assumed to be the aircraft behind traveling at 600 kts and the lead aircraft traveling at about 120 kts for an aft encounter with a closure rate Δd/Δt = 8 NM/min. In this case the acquisition range for an alert time of 4.5 minutes is R = 8 NM/min * 4.5 min = 36 NM. However, since a Level A3 system is also an A2 system with a minimum acquisition range of 40 NM in all directions (see Table 2-4), the minimum acquisition range aft for an A3 is also 40 NM.



$$y = y_0 - vt \qquad r = r_0 - ut$$

$$d = \sqrt{y^2 + r^2 + 2yr\cos(B)}$$

$$\frac{\Delta d}{\Delta t} = \frac{yv + ru + (yu + rv)\cos(B)}{d}$$

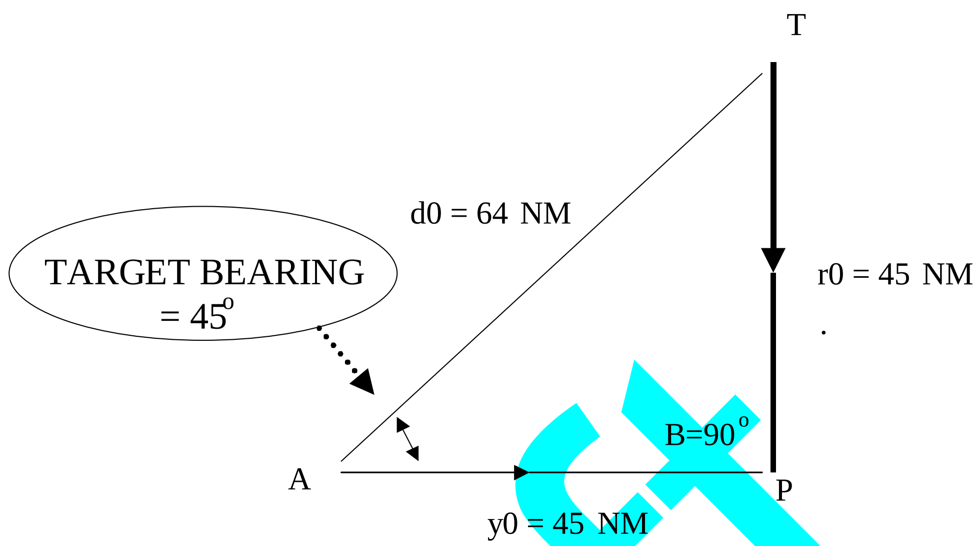
Figure D-1: Encounter Dynamic Relationships

D.3 Required Reception Range by Target Bearing Angle

The following material builds upon the analysis in §D.2 above and provides the analysis that drives the specific requirements for long range ADS-B reception as a function of the bearing angle from the receiving aircraft (referred to as own aircraft below) to the target aircraft. As used for the analysis in §D.2, the following additional analysis is based on a constant alert time, except otherwise qualified.

The intent of expressing the range requirements relative to target bearing is to provide a constant 4.5 minute acquisition range for encounters where the target aircraft is approaching from various bearing angles. The maximum aircraft velocity is set at 600 knots thus the maximum distance either own aircraft or target aircraft can travel in 4.5 minutes is 45 NM. This leads to the 90 NM requirement from Table 3-34 being applicable to a head-on encounter.

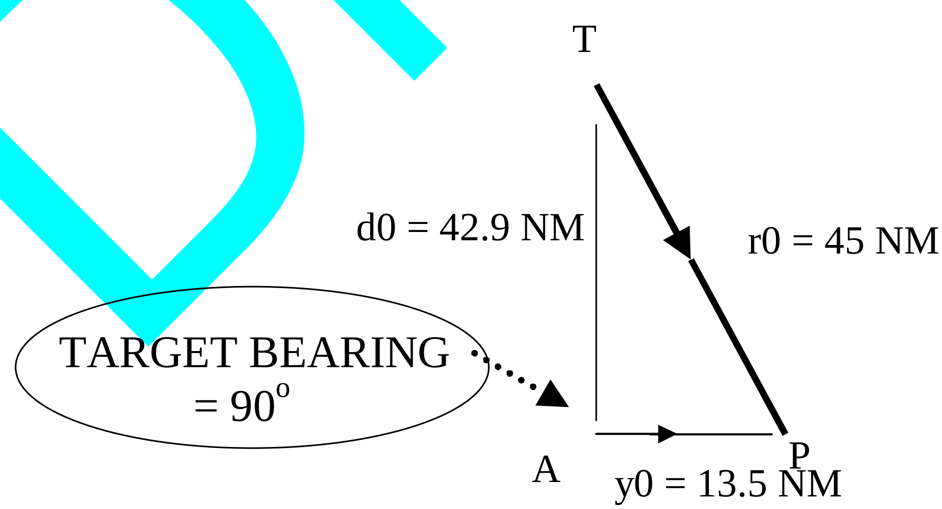
Referring back to Figure D-1, with angle B=90 degree for the crossing encounter this figure can be more simply accurately redrawn as shown in Figure D-2 below.



<u>Figure D-2:</u> Crossing Encounter with 45 Degree Target Bearing Angle

Thus a 64 NM reception range requirement for Class A3 avionics is appropriate for an encounter where the target aircraft is approaching at a bearing of ±45 degrees from the forward direction.

The worst case for a true port or starboard target bearing encounter (i.e., ±90 degrees from forward direction) and where own aircraft is operating at the minimum velocity and where the target aircraft is approaching at the maximum velocity (i.e., 600 knots). For this analysis own aircraft is assumed to be operating at 180 knots. This value was selected as it was considered the minimum velocity realistic for an aircraft in high enroute airspace. This scenario would result in the following maximum port and starboard air-to-air range requirement as depicted in Figure D-3.



<u>Figure D-3:</u> Crossing Encounter with 90 Degree Target Bearing Angle

The worst cast Port or Starboard encounter (requiring maximum air-to-air acquisition range) is where own aircraft (A) has a velocity of 180 knots and the target aircraft (T) has a velocity of 600 knots, the required range is 42.9 NM in order to provide target tracking for 4.5 minutes before point of closet approach. For the purposes of specifying the required reception range in these MASPS this was rounded up to a 45 NM requirement for Port and Starboard reception range.

Using the same approach as described for the cases above, the worst case scenario for where the target aircraft is being acquired at a bearing angle of ±45 degrees from aft, would be where own aircraft is being overtaken by a faster target aircraft. For this worst case geometry own aircraft velocity is 180 knots and the target aircraft velocity is 600 knots. This scenario results in a required reception range of approximately 35 NM for a 4.5 minute time to point of closest approach. However, since other applications require Class A3 avionics to have a minimum reception range of 40 NM for all target bearing angles, the required reception range for this case is set to this minimum bound for this case.

Finally for the aft reception range analysis the worst case overtake scenario is where own aircraft velocity is 180 knots and is being overtaken by a target aircraft with a velocity of 600 knots. For this case, the required aft reception range would be 31.5 NM for 4.5 minutes to point of closest approach. However, since other applications require Class A3 avionics to have a minimum reception range of 40 NM for all target bearing angles, the required reception range for this case is set to this minimum bound for this case.

D.4 Antenna Coverage Analysis

Since closure rates vary with bearing for fixed speeds, one possible design approach is to tailor the receive antenna coverage gain as a function of bearing angle (B when $y_0 = 0$) so that the detection range corresponds to a constant response time for any aspect angle. In this case, for example, the desired detection range for nonmaneuvering initial tracks might be the range required to assure a minimum separation of three miles after an avoidance maneuver, plus a range corresponding to a two minute response time in which to recognize the threat and execute this maneuver, plus a range corresponding to 30 sec to acquire the threat track.

Figure D-4 shows resulting detection ranges for such a constant alert time in two scenarios. The solid curve is the range required when own speed v = 600 kts and threat speed u = 600 kts. In this case a range of 53 NM is needed for the maximum closure rate at B = 0°, but only the 3 NM guard range is needed in the B = 180° direction since the threat aircraft never overtakes aircraft A. A scenario with v = 300 kts and u = 600 kts is illustrated by the dashed line in the same figure. Here the B = 0° range is reduced to 40 NM but the B = 180° range increases to 15.5 NM due to the higher speed overtaking aircraft.

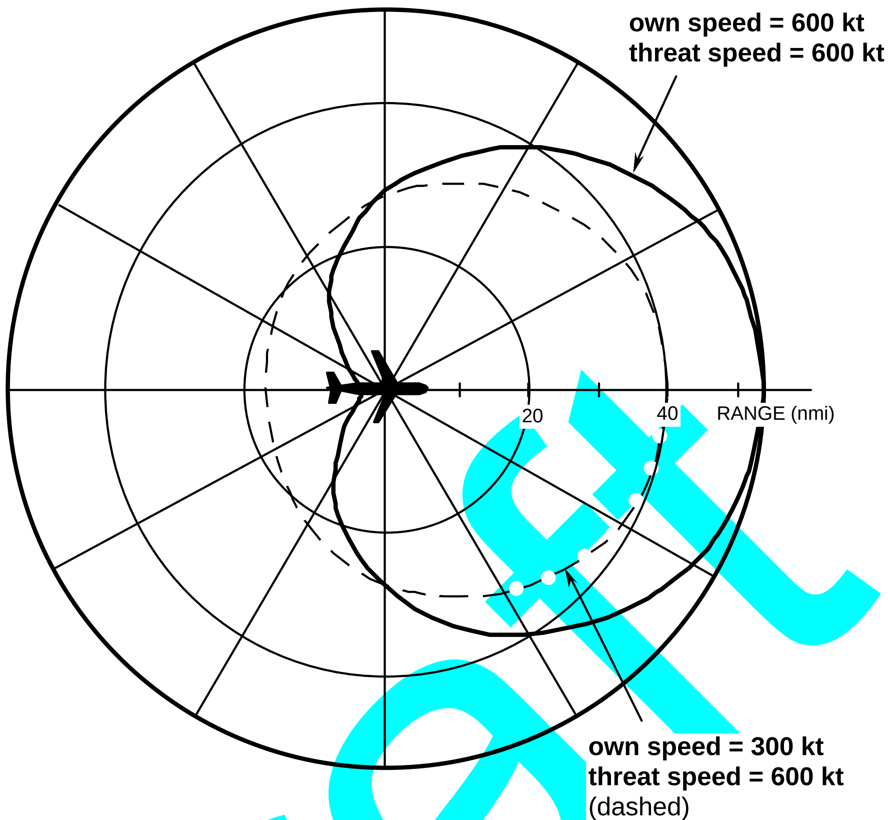


Figure D-4: Constant Alert Coverage for a) *v* = 600, *u* = 600 (solid curve), and b) *v* = 300, *u*= 600 kts (dotted curve)

Since both the above scenarios (or something similar) may be equally likely in certain airspace, both threats must be accommodated by the same antenna design. The normalized received antenna coverage, therefore, must be a compromise between the two requirements. That is, some gain reduction in the forward direction must be accepted in order to assure coverage at other aspect angles. With a fixed transmit ERP, the receive antenna gain must be proportional to the square of the range for a constant received signal. The square of the composite range in Figure D-4 is compared in Figure D-5 (solid line) with the normalized forward only coverage (dotted line). In both cases, $(R/R_0)^2$ in the forward direction is 0.5 at approximately B = ±70°. As shown in the related unnormalized antenna patterns (in dB) of Figure D-6, this corresponds to the full -3 dB beamwidth ($2B_0$) of the matched receive antenna. Comparison of the required antenna coverage (solid line in Figure D-6) with the forward only coverage (dotted line) shows the required front-to-back gain ratio must be limited to about 10 dB.

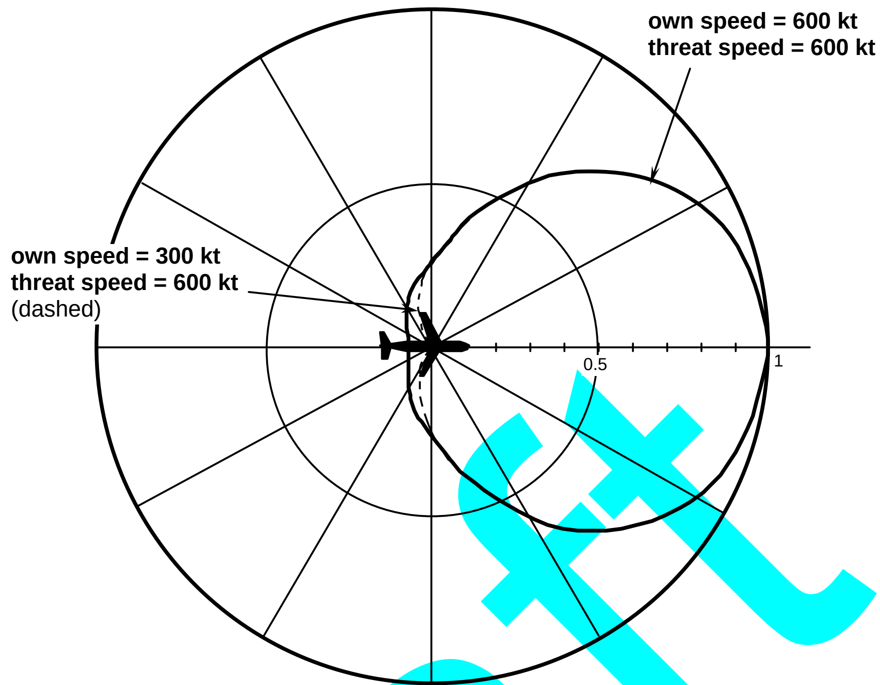
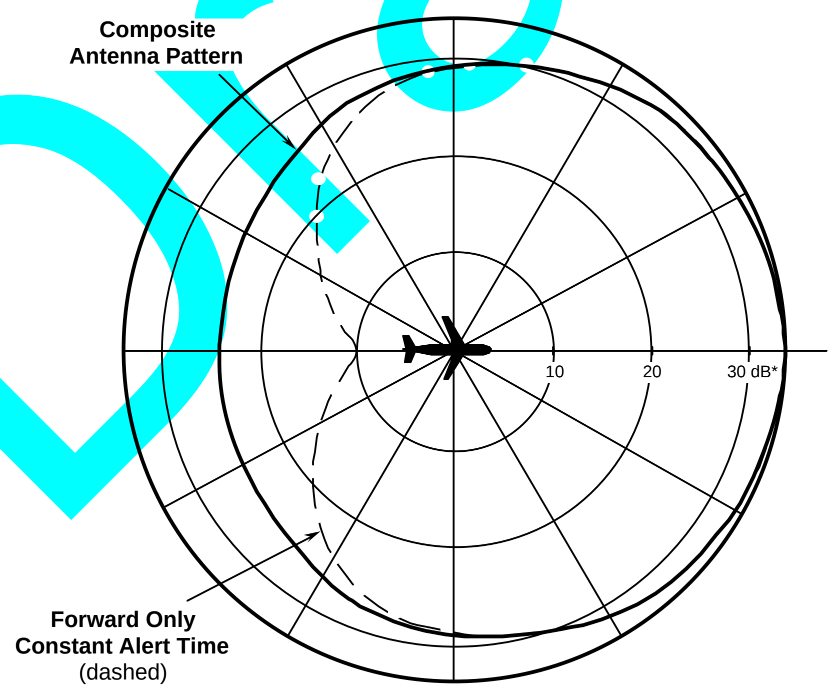


Figure D-5: Normalized Comparison of Range Squared Variation for a) *v* = 600 (solid curve), *u* = 600 and b) *v* = 300 and *u* = 600 kts (dotted curve)



* Note. Antenna gain values not normalized.

Figure D-6: Comparison of Composite and Forward Only Constant Alert Time Antenna Patterns in dB (No Normalization of Peak Gain)

A more general examination of angular coverage requirements when the threat aircraft is initially detected on a radial track with speed, *u*, follows. In this case, y = 0, and the rate of decrease in slant range becomes

$$\frac{\Delta d}{\Delta t} = \frac{u + v\cos(B)}{u + v} \qquad (2\text{-}1)$$

With half the -3 dB beamwidth, B_0, defined by $B = B_0$ when $\Delta d/\Delta t = 1/\sqrt{2}$, we have

$$B_0 = \arccos\left[\frac{(1-\sqrt{2})u + v}{\sqrt{2}v}\right] \qquad (2\text{-}2)$$

Coverage to the rear is assured by requiring the back-to-front antenna pattern ratio, F dB, to be F = $10\log(\alpha)$ where α is the square of the ratio of the back detection range to the front detection range. Using $B=180^0$ and $B=0^0$ in a square of the ratio formed from equation (2-1),

$$\alpha = \left(\frac{u - v}{u + v}\right)^2 \qquad (2\text{-}3)$$

We may estimate the relative gain of the receive antenna matched to these directivity and back-to-front ratios by recalling the directive gain approximation,

$$G\ \text{dB} = 10\log\left(\eta\frac{180^o}{B_0}\right) \qquad (2\text{-}4)$$

where G dB is relative to an omni antenna and η is a directivity efficiency factor defined by

$$\eta = \frac{\int_0^{\varphi_0} P(\varphi)d\varphi}{\int_0^{\varphi_0} P(\varphi)d\varphi + \int_{\varphi_0}^{\pi} P(\varphi)d\varphi} \qquad (2\text{-}5)$$

where $P(\varphi)$ is the antenna gain pattern, and φ_0 is half the 3 dB beamwidth for a symmetrical pattern. An estimate of the effect of the back-to-front ratio on efficiency can be readily obtained by approximating the real antenna pattern by a normalized keyhold model with $P(\varphi) = 1$, $0 \le \varphi < \varphi_0$; and $P(\varphi) = \alpha$, $\varphi_0 \le \varphi \le \pi$. From the keyhold pattern approximation,

$$\eta \simeq \frac{\varphi_0}{\varphi_0 + \alpha(\pi - \varphi_0)} \qquad (2\text{-}6)$$

Replacing φ_0 in radians with B_0 in degrees, and substituting (2-3), this becomes

$$\eta \simeq \frac{B_0}{B_0 + \left(\frac{u-v}{u+v}\right)^2 (180 - B_0)} \qquad (2\text{-}7)$$

Substitution of (2-2) and (2-7) into (2-4) yields the desired expression for the receive antenna gain (relative to an omni antenna) when constrained by a constant alert requirement for a threat aircraft at a speed, u, on any threat radial angle, B.

These generalized results are most easily understood by normalizing u to the own platform speed, v. Figure D-7 shows the variation in B_0 for normalized threat aircraft speed ranges $0.1 \leq u/v \leq 6$. Notice that B_0 is about 70° for the previous examples with normalized speeds in the range of $u/v = 1$ and 2. Notice that B_0 can only be less than 70° if the threat speed, u, is always less than own speed, v or $u/v < 1$. On the other hand, B_0 approaches an omni antenna as the potential threat speed becomes much larger than own speed.

Relative gain, G dB, for a receive antenna matched to a normalized threat speed, u/v, is plotted for $1 \leq u/v \leq 6$ in Figure D-8. This dependence on B_0 and F is given by equation (2-4) with the backlobe parametric substitutions described above. Notice that as expected, G = 0 dB (or, the gain of an omni antenna) as u/v increases. Although a relative gain of over 4 dB could be implemented, this assumes that the threat aircraft is never any faster than the own aircraft. A more conservative design point might be to assume u/v ^{2} 1.5. Then G ≤ 3.5 dB.

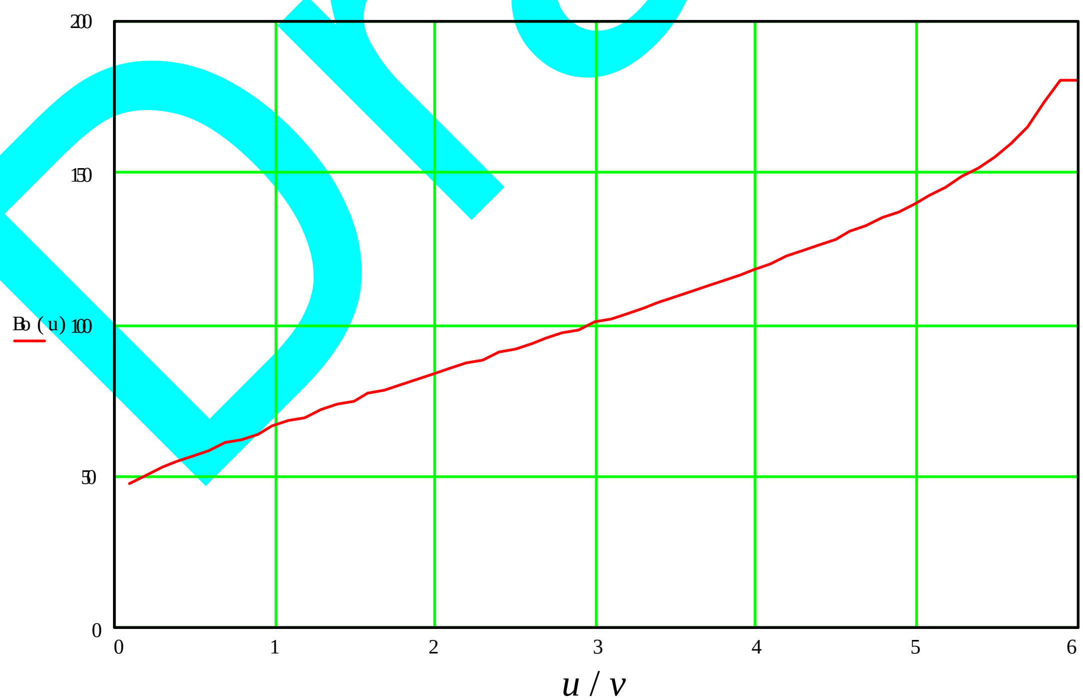


Figure D-7: Half Beamwidth Variation with Normalized Speed of Potential Threat

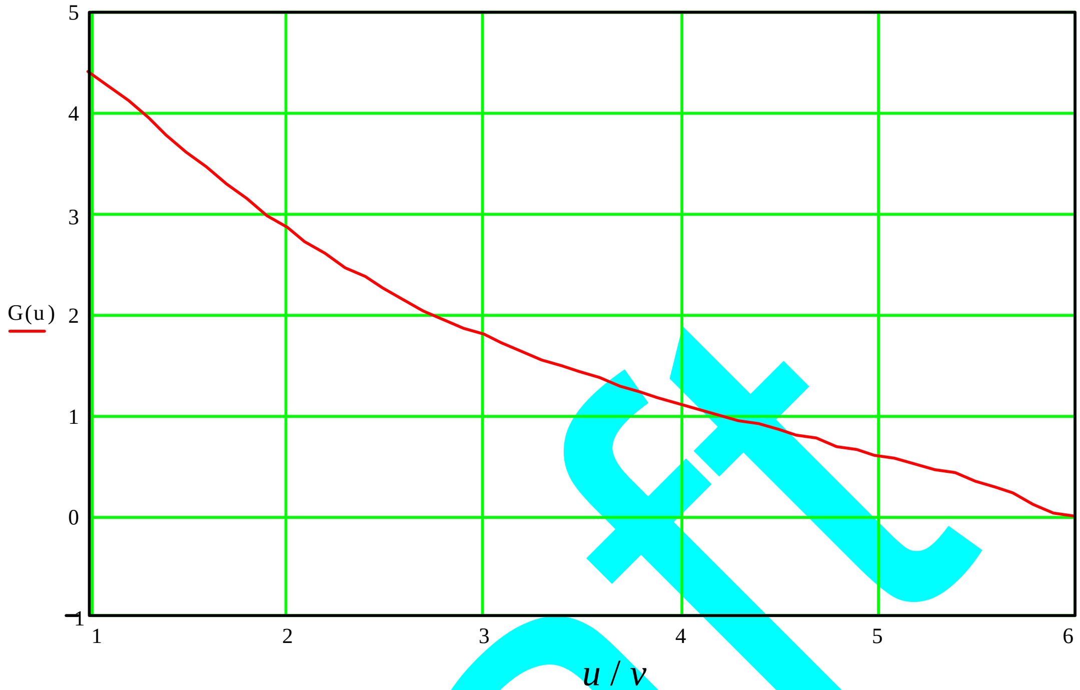


Figure D-8: Relative Gain of Matched Antenna as a Function of Normalized Threat Speed

Using a relative gain of 3.5 dB for the receive antenna gain in the link budget equation increases the range relative to that of an omni receive antenna by a factor of 1.5. Further improvements in detection ranges must be achieved by the use of multiple sector coverage antennas or by receiver sensitivity improvements.

D.5 Conclusion

Omnidirectional patterns are required on ADS-B aircraft transmit antennas serving ground-based ATC surveillance. A separate aircraft receive antenna may, however, employ directivity to increase coverage in the forward direction if no ground/air uplink from ATC is implemented. Peak gain in the forward direction for this separate antenna appears to be limited to about 3.5 dB relative to an omni receive antenna. This gain limitation is determined by response time requirements over all azimuth angles and uncertainties in expected speeds of threat aircraft. A 3.5 dB gain increase in the forward direction increases the link budget detection range by about 50 percent. Further increases in coverage require a more complex management of simultaneous sector coverage receive antennas, or receiver sensitivity enhancements.

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Appendix E

Performance Requirements to Support Air-to-Air Use of Target State Reports

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E Performance Requirements to Support Air-to-Air Use of Target State Reports

Target State (TS) data conveys intent information related to aircraft control state and equipment. TS Reports correspond to short term intent. The intent information provided in TS reflects aircraft states and targets entered by the pilot or programmed into the transmitting aircraft's automation system. None of the air to air applications currently defined in these MASPS require or utilize TS data and the information that is provided is expected to be utilized by Ground ATC to support awareness of the pilot's current selected altitude and heading. To assist in the interpretation of the selected altitude and heading, additional information indicating the operating mode of the flight control systems of the aircraft is also conveyed. Also, the barometric pressure setting is included to support air traffic control. It is anticipated that future air to air applications may require TS data. The future air to air applications which were envisioned in previous versions of these MASPS (RTCA DO-242A) served as the basis for the performance requirements for the transmission of TS data and the update requirements for TS Reports. Although the use of TS data may have changed, the performance assumptions have not been changed and are provided in the following sections so that future applications can potentially utilize this short term intent information.

E.1 Target State Report Acquisition, Update Interval and Acquisition Range

Target State (TS) report update periods and acquisition range requirements are summarized in Table E-1. These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting TS within the specified acquisition range or time interval.

Note: *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for the when loss of required separation will occur. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

The requirements for the minimum update periods for TS reports are functions of range. Tighter requirements (smaller required update periods) are desired on these reports for a time period equal to two update periods immediately following any major change in the information previously broadcast as specified in §3.4.7.2 and §3.4.8.2. These requirements are specified in terms of acquisition range and required update interval to achieve a 95% confidence of receiving a TS within the specified acquisition range or time interval.

The nominal TS report update period for A2 equipage at ranges within 40 NM and for A3 equipage at ranges in the forward direction within 90 NM **shall** {from 242AR3.21} be T_U, such that

$$T_U = \max\left(12\,s,\quad 0.45\frac{s}{NM}\cdot R\right)$$

where R is the range to the broadcasting aircraft and T_U is rounded to the nearest whole number of seconds. If implemented, these requirements are applicable to TS report update rates for A1 equipment for ranges of 20 NM or less.

Notes:

1. *It is desired that requirement 242AR3.21 should be met by A2 equipment at ranges up to and including 50 NM and by A3 equipment up to and including 120 NM.*

2. *Future versions of these MASPS might include higher update rates when there is a major change in the intent information being broadcast. Rates in the order of* $T_U = \max\left(12\,s,\quad 0.22\frac{s}{NM}\cdot R\right)$ *are under investigation for future applications and should be considered desired design goals.*

Table E-1 shows the values for the required minimum update periods as calculated by the above formulae at the ranges indicated as required and desired for A2 and A3 aircraft.

If the TS report is implemented in ADS-B systems of equipage class A1, such systems **shall** {from 242AR3.22} have a 20 NM acquisition range for TS Report. For equipage class A2, the acquisition range for TS reports **shall** {from 242AR3.23} be 40 NM, with 50 NM desired. For equipage class A3, the acquisition range for TC reports in the forward direction **shall** {from 242AR3.24} be 90 NM, with 120 NM desired. The range requirements in all other directions for A3 equipment **shall** {from 242AR3.25} be consistent with those stated in Note 3 of Table E-1.

Table E-1: Summary of TS Report Acquisition Range and Update Interval Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**				
Applicable Range →	**R ≤ 20 NM**	**R <= 40 NM**	**R <= 50 NM**	**R <= 90 NM**	**R <= 120 NM**
Equipage Class →	A1 optional A2 required	A2 required	A2 desired, A3 required	A3 required	A3 desired
TS Report Acquisition Range	20 NM (A1 optional)	40 NM (A2, A3 required)	50 NM (A2, A3 desired)	not required	not required
TS Report state change update period (note 3)	12 s	12 s desired (See note 2 above.)	12 s desired	not required	not required
TS Report nominal update period	12 s	18 s	23 s desired	not required	not required

Notes for Table E-1:

1. *Table E-1 is based on an air-air en route scenario between two aircraft closing at 1200 knots, which is considered a worst-case scenario for deriving range requirements for ADS-B conflict alerting.*

2. *The ranges shown in Table E-1 are meant to represent operational airspace with aircraft densities equivalent to those defined in Table 2-4.*

3. *The trigger conditions for the desired broadcasting of TS reports at the “state change” update rate are specified in §3.4.7.2.*

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Appendix F
Track Acquisition and Maintenance Requirements

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F Track Acquisition and Maintenance Requirements

F.1 Introduction

ADS-B surveillance information required to support various operational needs is transmitted differently depending on the data link. If information is transmitted using different message types, the receive processor must correlate information contained in the different message types from different aircraft and associate this information with the correct source aircraft. These correlated, time registered data are then provided to the on-board user application in the form of ADS-B reports. Depending upon the design, the ADS-B receive processor may also support additional functions that are traditionally considered to be part of surveillance tracking. The following discussion first reviews the familiar role of trackers employed in radar surveillance and then identifies some of the ways the ADS-B tracker function differs from radar tracking. ADS-B link reliability required to support ADS-B tracking is then discussed in Sections 2, 3, and 4.

Radar trackers are a familiar part of both skin paint (PSR) and cooperative (SSR) radar surveillance systems, but ADS-B report information content and quality of the information differs appreciably from the target estimates available from a radar sensor. The following discussion identifies some of these differences, discusses the impact of these differences in defining ADS-B tracker requirements, and illustrates how tracker-related features influence the determination of acceptable ADS-B link interference limits.

F.1.1 Radar Trackers

Radar surveillance systems output position (and sometimes other parameters such as altitude and radial-velocity) estimates on each target detected during a beam scan. Extraneous detections (clutter in the case of PSR and FRUIT replies in the case of SSR) are also output during the beam scan. Trackers are used to suppress these extraneous detections while maintaining surveillance on targets of interest. The process of sorting out extraneous detections from desired detections is based on the expected behavior or scan-to-scan consistency of desired target detections in contrast with the more random nature of undesired detections. This sorting, or track acquisition, process requires that at least m out of n successive scan detections have some kind of correlation in order to initiate a new track. This correlation requirement reduces the probability that extraneous detections (false alarms) will be forwarded to displays or surveillance algorithm using this data.

Radar trackers also smooth target position estimates and derive target velocity estimates based on successive position estimates. This derived velocity is updated with each position estimate and can be used to coast the tracked target through periods of missed updates as long as a new update is obtained before the track coast period has exceeded some operationally accepted interval. For example, the acceptable coast interval may be limited by the required track correlation bin size, or by the time allowed before detection of a worst case threat maneuver by a track in the coast state. Coast periods for the relatively close TCAS target separations are limited to less than ten seconds; coast periods for en route radar traffic environments, on the other hand, are tens of seconds. Similar time considerations apply to initial acquisition of pop-up targets or reacquisition of dropped tracks.

F.1.2 ADS-B Trackers

ADS-B surveillance and supporting tracker considerations differ from radar in several respects:

- ADS-B extraneous decodes are produced by undetected message errors; these are extremely rare with use of forward error detection codes. All correctly decoded ADS-B messages contain valid surveillance related information on some aircraft within detection range.
- ADS-B information exchanges are of three types: 1) State Vector data (SV) which are broadcast at a relatively high rate, 2) Mode Status data (MS), and 3) future intent data. MS data, or MS and future intent data may be contained in the same message as SV data in some designs, or MS and future intent data may be broadcast as separate messages at a lower rate. All messages in any design contain the transmitting aircraft address. Different operational capabilities require receipt of different levels of information. For example, SV data alone aids visual acquisition of targets and supports basic conflict avoidances; higher levels of operational capability require augmentation of SV data with MS data, or MS and future intent data.
- Different ADS-B message types from the same aircraft are unambiguously associated with the same aircraft track through the above mentioned aircraft address contained in each message. Since ADS-B SV messages contain high accuracy velocity data, there is no need for tracker derived velocity estimates based on the difference in successive position updates. A tracker employing extrapolation, correlation, and smoothing is required, however, to reassemble segmented position and velocity SV messages if they are used.

F.1.3 Operational Needs

Dynamic considerations associated with following an aircraft maneuver using ADS-B based surveillance are similar to those for radar tracking. Certain benefits are, however, obtained from the complete target state vector and other operational information provided in received ADS-B messages. Acquisition ranges and the information exchange requirements for the operational applications of interest are summarized in Table 3.-34.

Surveillance on target separations out to about 20 nmi may be supported by only the position, velocity, and aircraft address information contained in the full state vector (SV) message. These tracks, once acquired, may be maintained by reception of at least one full SV message update within the permitted track coast interval. An acceptable coast interval is somewhat dependent on the operational application supported, but might typically be defined as two update opportunity (or broadcast) intervals. IFR traffic separation requirements impose the need for information in addition to the SV, such as aircraft identification and flight status that is included in the augmenting Partial Mode Status (MS-P) message type. Since MS-P information is relatively static and is directly associated with SV messages through the common aircraft address, it does not require the same broadcast rate as SV messages. Both SV and MS-P messages must be received, however, to support this IFR operational need.

Predicting aircraft separations based on SV information alone is limited to the above mentioned separations of about 20 NM by false alerts due to aircraft plant noise (normal variations in the track angle during flight) and the fact that the aircraft of interest may maneuver during the approaching encounter alert interval. Beyond 40 NM, after initial SV, MS and future intent data are acquired, a received SV update interval equal to that of current en route radars seems adequate at these separations. Permitted coast intervals are correspondingly longer.

As discussed above, while maneuver dynamic data contained in SV messages alone support track requirements for separation from nearby aircraft, different operational concerns drive requirements for initial acquisition and track of more distant aircraft. In the latter case, if the operational application requires a specified alert and response time (determined by operational considerations), then the time required to accumulate the required SV, MS and future intent information must be added to the operationally required alert time when determining the maximum detection range required for the supported application.

Various combinations of ADS-B state vector broadcast update rates, MS and future intent broadcast arrangements, and probabilities of correct reception can satisfy the above stated track acquisition/reacquisition and track maintenance requirements. The following examination determines minimum acceptable values supporting tracker operation. These message reception probabilities may limit the effective range of a particular design when it operates in a high interference environment. Several design alternatives (representing possible random access and TDMA system designs) are shown to illustrate performance tradeoffs. It is assumed that all the required information is contained in either a full state vector report or in segmented state vector reports. Operations requiring the reassembly of augmenting information exchanged in additional message types are then considered.

F.2 Approach

F.2.1 Assumptions

The information elements required for various surveillance applications and the coverage ranges of interest are summarized in Table 3-34. It has been previously shown that required SV update intervals for conflict avoidance is 3 seconds and, optimized separation is about 6 seconds. on the basis of acceptable loss in alert time for a specified threat target maneuver. From the ADS-B report assembly perspective, we are also interested here in 1) how long it takes to acquire the SV and any necessary augmenting information for the application of interest, and 2) the probability that the acquired track will be dropped if not updated by an SV message within the assumed coast period of two report update intervals. Acquisition time requirements for this examination are assumed to be 6 seconds at a 99% confidence level for conflict avoidance (this is slightly higher than the 95% value given in Table 3-34) and 15 seconds at a 95% confidence level for optimized separation. A reasonable value for the acceptable probability of a dropped track depends on the operational environment, but is taken here to be 0.01. Only random interference is considered. That is, all targets are assumed to be within detection range and received messages are above the link fade margin.

F.2.2 Design Alternatives

The following analysis determines the lowest acceptable probability of correct message decode, P_s, required to meet tracker requirements for the following message broadcast design alternatives:

1. SV messages are segmented with alternate broadcast of position and velocity messages at intervals of 0.25 sec between segment transmissions. MS and future intent messages are each transmitted in separate messages at intervals of T_s= 5 sec for each if either is transmitted alone, or on intervals of 2.5 sec. if both message types are required. That is, the interval for both MS and future intent transmissions is 5 sec. The net transmission rate for segmented SV, MS, and future intent messages is thus 4.4 Hz per aircraft supporting applications requiring additional information that is conveyed in an additional MS or future intent message. The rate is 4.2 Hz for all others broadcasting SV and MS data. These assumptions represent a possible random access design.

2. Full SV data and MS data (partial or full) are combined in one message and broadcast at intervals of 1 sec or 3 sec. Separate future intent messages are interleaved with these SV/MS messages as needed on a T_s= 6 sec frame interval in these two designs. The one second interval represents an alternate random access design. The three second interval could be representative of a TDMA design.

3. Each message contains all SV, MS and future intent data and broadcast at intervals of 3 sec. This represents an alternate TDMA design.

F.3 Analysis

F.3.1 Performance with State Vector Only

Based on TCAS and simulation experience, assume an ADS-B tactical separation track is updated at intervals of t sec, and is dropped if an SV update is not received within T_d =6 sec. An ADS-B design with a state vector update interval, t, (t=1/update rate) has m_d=T_d/t opportunities to update the track before it is dropped. For at least one success in m_d tries, the probability of maintaining a track during the permitted coast interval is then

$$P_d = 1 - (1 - p)^{m_d} \quad ; m_d = T_d/t \qquad (3\text{-}1)$$

where p is the single report probability of correct reception and each try is assumed to be independent.∗

Full State Vector

∗ The assumption of independence applies for random interference or low S/N considerations. Link fading must be treated separately.

Because an ADS-B report provides full dynamic information on the aircraft of interest, a single full SV message is adequate for SV data acquisition. Track acquisition or reacquisition within some fraction, α, of the coast period requires at least one out of m full state vector updates. The probability of acquisition is thus given by

$$P_{acq} = 1-(1-p)^m \tag{3-2}$$

where $m= \alpha T_d/t$. When $\alpha= 1$, $m= m_d$.

Segmented State Vector

Acquisition of segmented state vector reports is a little different. In this case, both the position report segment and the velocity report segment must be received and correlated to initiate track. For interleaved segmented reports and the same broadcast rate,

$$P_{acq} = [1-(1-p)^{m/2}]^2 \tag{3-3}$$

since both segments must be received and each segment is transmitted only m/2 times in the permitted acquisition interval.

Minimum Acceptable Decode Probabilities

Equation (3-2) and (3-3) show the probability of receiving at least one full state vector update out of m opportunities to receive an update as a function of the single try probability of receiving an update, p. If, as in equation (3-1), $m= m_d$, then (3-2) and (3-3) give the probability of maintaining a track requiring an SV update within $T_d=m_d t$ seconds. With a little manipulation, (3-2) may be rewritten as:

$$P_f = 1 - q^{1/m_d} \tag{3-4}$$

where $q=1-P_{acq}$ and is the probability the track is dropped if not updated within T_d sec. The single report probability $p=P_f$, is the minimum probability supporting an acceptable probability of track loss, q with a full SV broadcast every t sec.

Now consider a segmented SV design alternately transmitting position and velocity messages at a rate of n segments in t seconds. The probability of a full SV update in t seconds is then given by (3-3) where m=n. An update capability equivalent to that of the full SV design within $T_f=m_d t$ sec may then be determined by setting this value equal to P_f in (3-4) and solving for the required probability of decoding each of the segmented SV messages, P_s. The resulting minimum value for segmented SV messages is

$$P_s = 1-\left(1-\sqrt{1-q^{1/m_d}}\right)^{2/n} \tag{3-5}$$

F.3.2 Performance with Augmenting Messages

Acquisition requirements for more distant aircraft that are not in immediate conflict may, as discussed above, be stated in terms of being (say) 95% confident of acquisition of the required information elements by the time the aircraft is within the required surveillance range. If P_{acq} is the probability of SV acquisition in an interval, αT_d, and initial acquisition is required within a time, T_{acq}, we may approximate the cumulative probability of State Vector information acquisition by assuming T_{acq} to contain h acquisition cells αT_d long. Thus, $h = T_{acq}/(\alpha T_d)$, and the cumulative probability of SV acquisition within a time, T_{acq}, is

$$P_{cum} = 1-(1-P_{acq})^h \qquad (3\text{-}6)$$

where P_{acq} is again given by (3-2) for full state vector reports, and (3-3) for segmented reports.

Since separation assurance applications require SV+MS data, and since applications at longer ranges may require future intent as well as MS+SV information, track acquisition is not achieved in these cases until the augmenting message(s) is/are also received. Augmenting information may be exchanged in two ways:

- Include MS and future intent data along with SV data in a single message broadcast at a rate 1/t
- Augment SV data (broadcast at a rate 1/t) with separate MS and future intent messages interleaved with SV messages at a lower rate ($1/T_s$), for example once every five or six seconds.

In the first case where a single message contains SV, MS and future intent information, extended range initial acquisition is also given by (3-6). The second case may be implemented in any of a number of different ways. To illustrate, consider the design based on segmented SV messages broadcast at an average 0.25 sec interval between SV segments, and with MS and future intent messages interleaved on a T_s= 5 sec average frame time as needed. The cumulative probability of acquiring SV+MS information within T= h x 5 sec is then

$$P_{CSM} = [1-(1-P_{sv})^h]\,[1-(1-p)^h] \qquad (3\text{-}7)$$

where P_{sv} is the probability of acquiring SV data within 5 sec given by (3-3) as

$$P_{sv} = [1-(1-p)^{10}]^2 \qquad (3\text{-}8)$$

and the second term in (3-7) is the probability of receiving the MS message within a period of h x 5 sec. If MS and future intent data are contained in separate interleaved messages, then the $[1-(1-p)^h]$ term in (3-7) is squared to account for the joint probability of receiving both MS and future intent as well as SV messages within T= h x 5 sec.

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F.4 Results and Discussion

Equations (3-2) and (3-3) are plotted in Figure F-1 for the segmented SV design with an update interval, t_s= 0.25 sec, and for full SV designs with update intervals t_f= 3 sec and 1 sec. As a matter of interest, a full SV design with t_f= 0.5 sec is also shown for comparison with t_s= 0.25 sec segmented SV design. Each curve shows the probability of obtaining at least one SV update within 3 sec as a function of the single message probability of correct decode, p. These values correspond to the requirements for a basic conflict avoidance capability operating without required IFR augmenting information.

As discussed above, the minimum required probabilities of message decode may also be related to operational needs by examining the single message decode probability required to assure that 99% of the tracks are updated within the specified coast interval of twice the operationally required update interval. Figure F-2 shows this minimum acceptable value dependence on 2x update interval for the above designs (equations 3-4, and 3-5). Here, as expected, each design accommodates some decrease in the required minimum value of p for SV or segmented SV messages as the permitted update interval increases. These acceptable p values, however, only apply in cases where all the operationally required information is contained in a single message type. If different message types are used, at least one message of each required type must be decoded for acquisition.

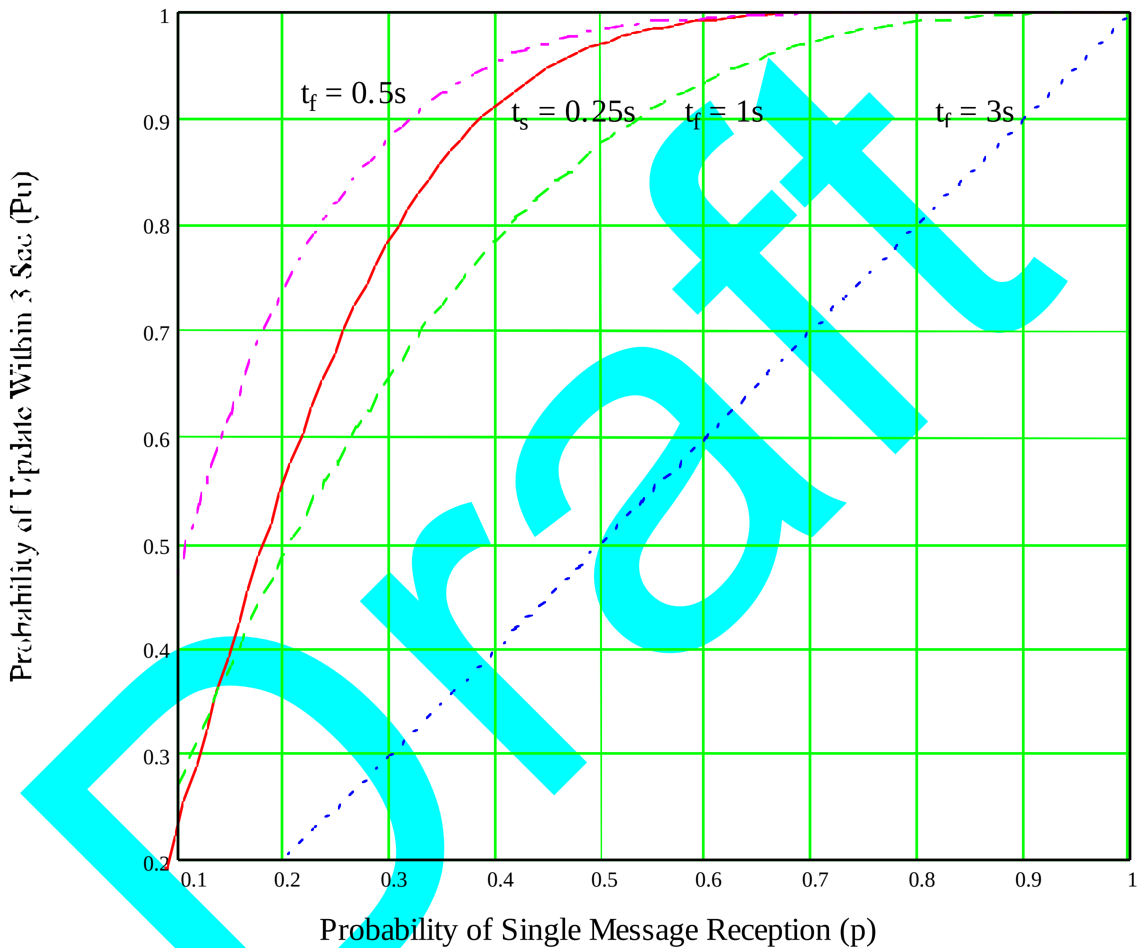

Figure F-1: Probability of Update Within 3 Sec Interval vs. Single Message Reception Probability for Several Broadcast Intervals

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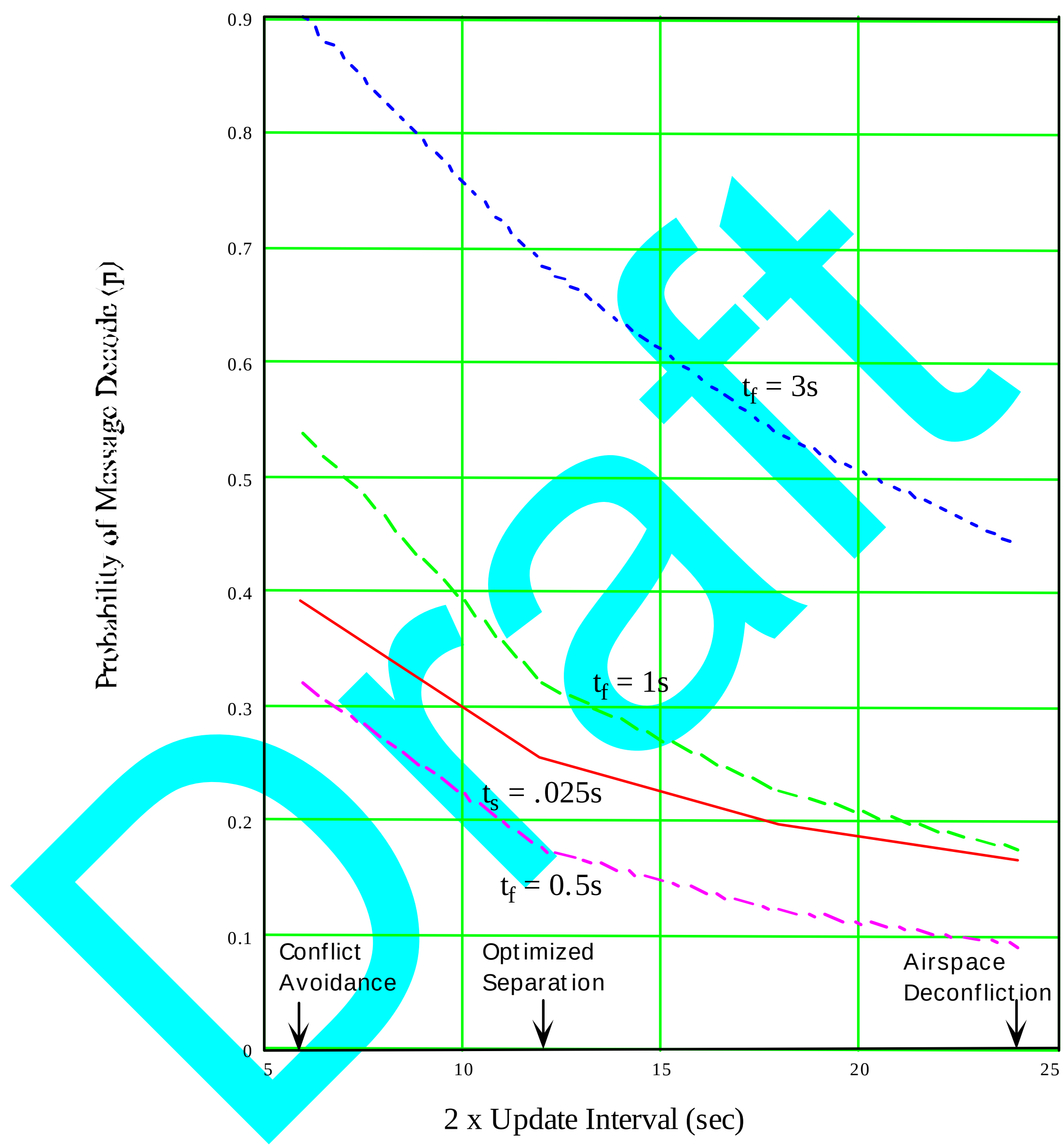

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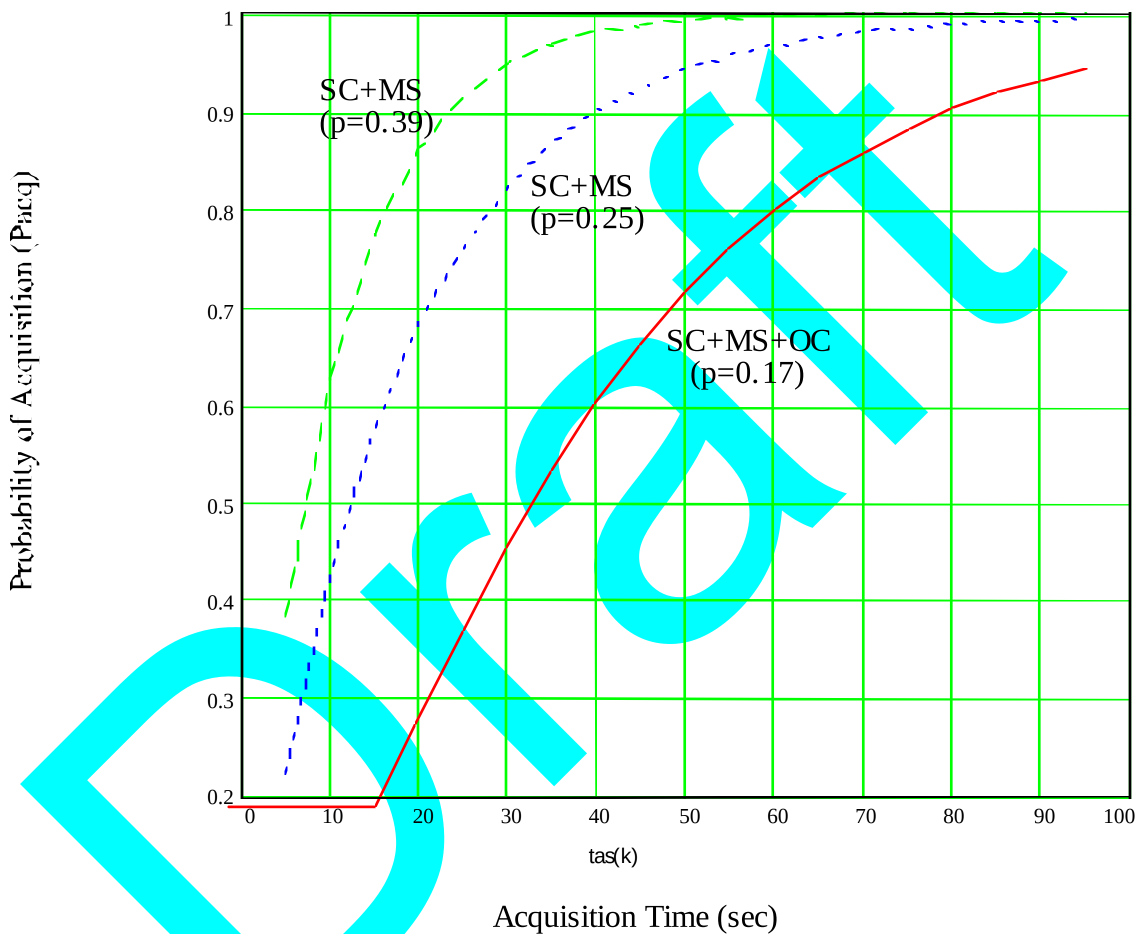
269 **<u>Figure F-2:</u> Required Probability of Message Decode vs. Twice the Required Update**
270 **Interval for 99% Confidence Track is Updated Within Twice the Update Interval**

271



<u>Figure F-3:</u> Probability of Acquiring Multiple Message Types for Segmented State Vector Design with t_s=0.25s and Augmenting Messages Interleaved on a T_s= 5 sec Basis

Although the minimum acceptable probabilities of decode, p, given in Figure F-2 show what is required to support SV track maintenance requirements for conflict avoidance update intervals of 3 seconds, ADS-B Separation update intervals of 6 seconds, and longer range update intervals of 12 seconds, all surveillance services except basic conflict avoidance require augmenting the SV update data with MS-P, MS or future intent type information. Figure F-3 illustrates how low values of p, which are acceptable interims of the SV update requirements alone, limit the acquisition process when multiple message types must be received in order to aggregate all the associated surveillance and intent information required for potential longer range applications. This figure is plotted for the segmented SV design and shows the probability of acquiring the full state vector, SV, as well as the required augmenting messages within the indicated acquisition time. Here we note that although p= 0.17 supports the 24 sec coast time of Figure F-2, the time to acquire the needed SV, MS and future intent data with this value of p is 95 seconds at a 95% confidence level. Either the system detection range must be adequate to support this long acquisition time, or operations must be limited to conditions where a higher level of p is obtained in order to acquire all required data within a shorter time say, 30 seconds. The other two curves on Figure F-3 show similar problems for the other operational services of interest: conflict avoidance, and optimal separation

Figure F-4 shows the same acquisition time relationship for the two designs combining SV and MS into one SV/MS message and augmenting this with an interleaved future intent message at T_s= 6 sec as needed. In this case the p= 0.44 value required for t_f= 3 sec track update also supports acquisition of future intent data within 30 seconds at a 95% confidence level. However, the lower value of p= 0.18 for the t_f= 1 sec design (acceptable for SV/MS update requirements) leads to long delays in future intent data acquisition

F.5 Summary

Table F-1 summarizes these results by comparing minimum acceptable p values determined only by SV track update requirements, with corresponding values derived on the basis that the augmenting MS and future intent message acquisition times are the determining factors. The table is based on the assumed requirements of a 6 sec acquisition time for conflict avoidance, a 15 sec MS acquisition time for ADS-B optimum separation, and a 30 sec MS and future intent acquisition time for longer range applications. As an illustration, at a 1200 kt closure rate, a 30 sec acquisition time adds 10 nmi to the required coverage in order to meet the desired alert time.

Inspection of Table F-1 shows that, using the assumed acquisition times and MS and future intent message transmission periods, augmenting message acquisition considerations are more demanding than track maintenance requirements for the segmented SV (t= 0.25 sec) design. This is also true for longer range applications with the SV/MS (t= 1 sec) design. Several possibilities may be considered in these cases:

1. Detection ranges may be extended to accommodate the long acquisition times.
2. The design SV and MS and future intent interleave rates may be changed.
3. Support of the intended operational capability may be restricted to low interference environments where higher values of p can be achieved.

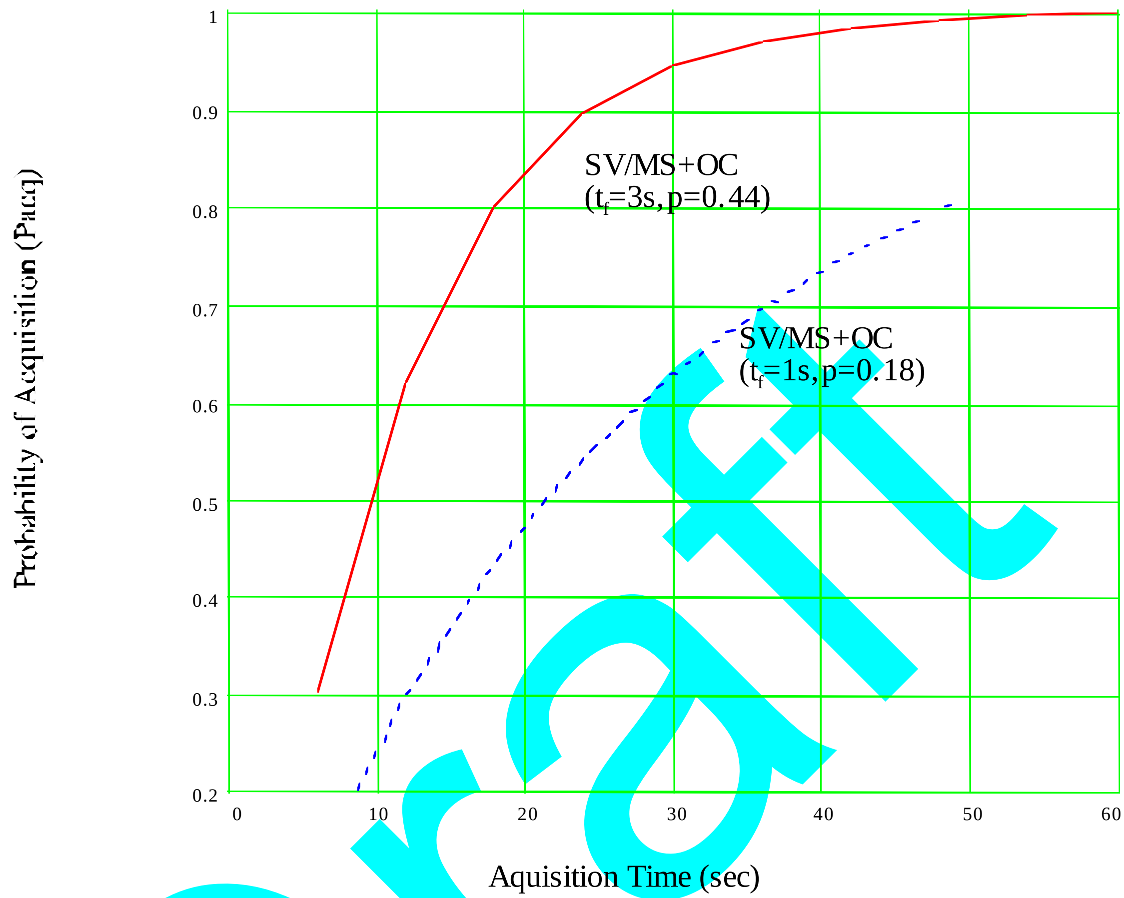


Figure F-4: Probability of Acquiring Augmenting Message for Full State Vector Plus Mode Status Design for t_f=3 sec and 1 sec with Augmenting Message Interleaved on a T_s= 6 sec Basis

Table F-1: Summary of Message Probabilities of Correct Decode Required for Each Design Alternative in Support of Desired Operational Capabilities

Design Alternative	Short Range T_d= 6 sec (99%) T_{acq}= 6 sec (99%)	Medium Range T_d= 12 sec (99%) T_{acq}= 15 sec (95%)		Potential Longer Range Application T_d= 24 sec (99%) T_{acq}= 30 sec (95%)	
	SV or SV/MS for T_d	SV or SV/MS only for T_d	SV+MS for T_{acq}	SV or SV/MS only for T_d	SV+MS and future intent for T_{acq}
Segmented SV t= 0.25 sec T_s= 5 sec	0.39	0.25 (note 1)	0.63	0.17 (note 1)	0.46
SV/MS t= 1 sec T_s= 6 sec	0.53	0.32	n/a	0.18 (note 1)	0.45
SV/MS t= 3 sec T_s= 6 sec	0.9	0.69	n/a	0.44 (note 1)	0.46
SV/MS/ future intent t= 3 sec	0.9	0.69	n/a	0.44	n/a

Notes:

1. *These values only support an indication of target presence. They will not support the intended application.*
2. *n/a indicates service requirement determined by T_d requirement.*

In summary, for any design, final system requirements must reflect the most demanding requirement determined by track maintenance, track acquisition time, and lost alert time considerations.

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Appendix G
Future Air-Referenced Velocity (ARV) Broadcast Conditions

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G Future Air-Referenced Velocity (ARV) Broadcast Conditions

G.1 Background

In this version of these MASPS, there are no conditions that require the transmission of air-referenced velocity data (heading and airspeed). There is optional transmission of ARV data in the event of loss of ground velocity to maintain tracks when ground data is lost. However, there are other future applications that could make use of ARV reports. Among those applications:

- Collision Avoidance and Separation Assurance and Sequencing: ARV data can be used to improve accuracy of conflict detection, prevention, and resolution routines when the transmitting aircraft is being controlled to either an air-referenced or a ground referenced velocity.
- For Interval Management and other future spacing applications, ARV data enables near real-time wind estimation and provides improved situation awareness for trailing aircraft.
- ARV data, allowing wind direction and speed estimates, provides improved real-time information for Ground ATC automation functions and supports improved weather monitoring.

G.2 Applications Benefited by ARV data

G.2.1 Collision Avoidance and Separation Assurance and Sequencing

G.2.1.1 Operational Scenarios

ADS-B receiving aircraft or ground stations can use ARV along with the ground track and ground speed (available through the state vector) to approximate wind information encountered by a transmitting aircraft. Consideration of winds should improve the performance of conflict detection, prevention, and resolution routines in cases where the transmitting aircraft is flown in a heading-referenced flight mode, or when the predicted flight path encounters changes in along-track winds. Operational examples include heading select and heading hold modes often used while being vectored by air traffic control or deviating around hazardous weather. Figure G-1 shows the effect of wind on an aircraft's ground track when turning from a northerly to westerly heading in the presence of a 30-knot wind from the south. The ground track is extended for two minutes after turn completion. Throughout the scenario, the aircraft flies at a constant true airspeed of 250 knots and maintains a constant bank angle corresponding to a standard rate turn (360 degrees in four minutes). For comparison, the no-wind ground track is also shown.

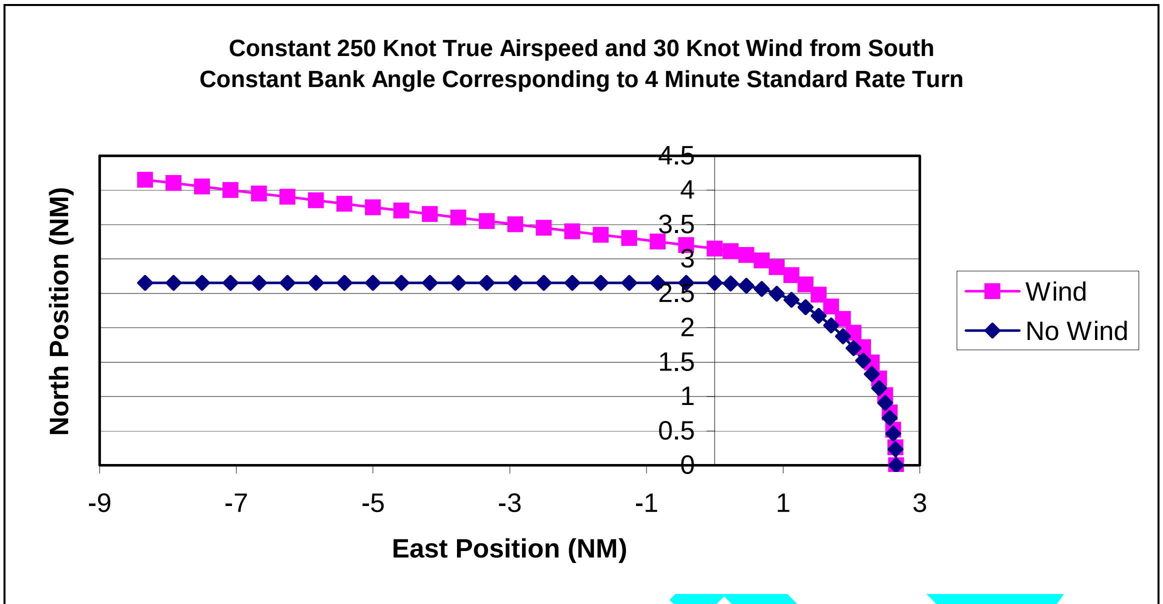

Figure G-1: Wind Effects on Heading-Referenced Flight Modes

In the wind condition, the aircraft completes the turn a half-mile north of the no-wind case. After flying in the crosswind for two minutes, the aircraft has drifted an additional mile to the north. The combination of these wind errors could affect the accuracy of predicted conflicts. Although this example assumes a simplified constant bank angle turn, the wind effects are apparent nonetheless.

Consider a second example of two aircraft engaged in an air-air separation assurance application. In Figure G-2, an aircraft operating in a heading hold mode is flying 3000 feet below another aircraft flying a defined ground track angle. The lower aircraft begins a constant 1500 ft/min climb and encounters a left crosswind that is 30 knots greater at the higher aircraft's altitude. This scenario is designed to represent the common occurrence of changing wind conditions with altitude. Each aircraft can combine the other aircraft's air and ground-referenced velocity vectors to approximate the wind encountered by that aircraft. Assuming each aircraft knows its own wind conditions, the wind differential encountered by the climbing aircraft can be approximated by a ramp function. Figure G-2 shows the ground track of the climbing aircraft in the presence of the ramp wind. The crosswind causes the climbing aircraft to drift a half-mile during the climb. If the climbing aircraft in this example were to encounter a changing headwind or tailwind component, the availability of ARV information would also enable a more accurate location and time prediction of the point in which it climbs through the other aircraft's altitude.

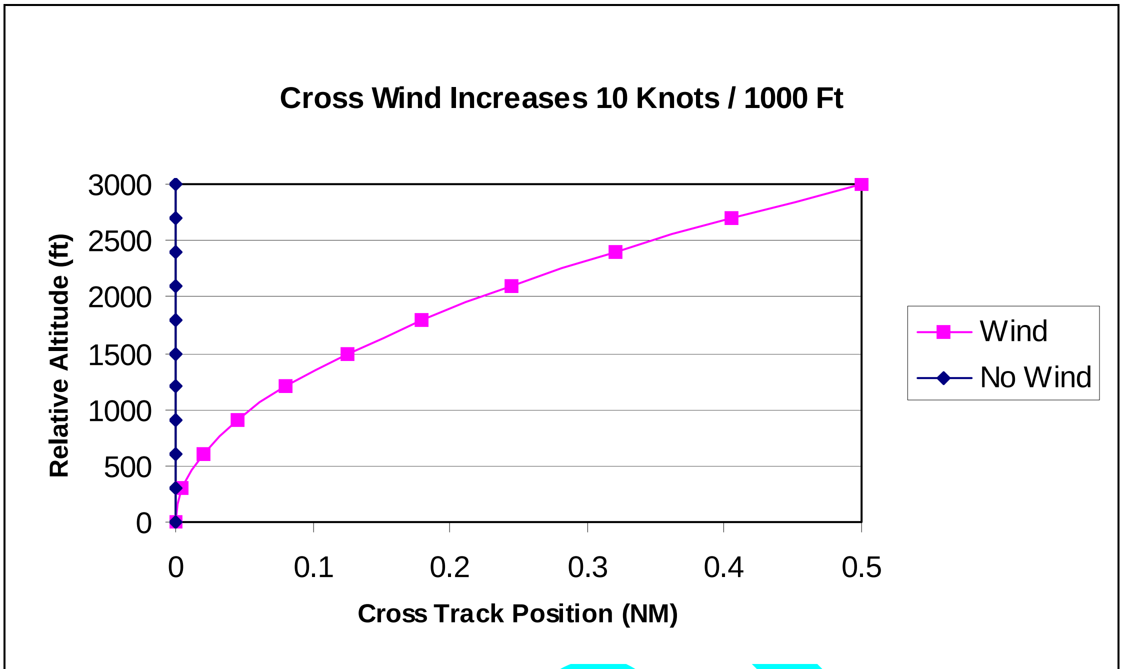

Figure G-2: Drift Due to Ramp Cross Wind

ARV broadcast while operating in comparable scenarios may be beneficial. Certain addressed datalink systems allow some aircraft to provide ground stations with current wind conditions [1]. Under this concept, ground-based command and control systems process incoming wind data and make them available to participating aircraft. However, ADS-B may enable more current and localized wind approximation for aircraft engaged in paired applications. ARV information is expected to be particularly beneficial when aircraft are operating in heading-referenced flight modes. It may also lead to improved predictions for fly-by turn segments. In normal conditions, winds do not affect aircraft predictions when flying straight and level ground-referenced legs.

Controllers may also benefit from ARV information when providing radar vectors and speed commands to sequence aircraft in the terminal area. Due to the inability of some aircraft to determine ground track and ground speed, controllers issue these commands in the form of magnetic heading and indicated airspeed. Controllers must anticipate the heading and airspeed targets needed in order to produce the desired ground track. This process often requires the controller to verify current heading and airspeed over the radio. After issuing vectors and speed commands, controllers have no direct way to ensure compliance. Direct broadcast of ARV information would enable more accurate control and would likely make this process easier [2].

G.2.1.2 Possible ARV Broadcast Conditions

In order to improve the accuracy of conflict detection, prevention, and resolution routines, ARV information should be broadcast at a rate sufficient to derive wind estimates for the ADS-B transmitting aircraft

In order to support air traffic control use of radar vectors and speed commands, the following ARV broadcast condition may be needed:

ARV information should be broadcast at a rate consistent with that for ADS-B state vectors when engaged in identified terminal operations such as approach transition, as indicated by an appropriate ADS-B air-ground service level or as identified by other means such as pilot input. The ARV information should continue to be broadcast until an appropriate signal or condition occurs that signifies that the information is no longer needed (such as arrival at the Outer Marker).

G.2.2 Spacing Applications

G.2.2.1 Operational Scenario

Spacing applications may also benefit from ARV information. Accurate wind information, potentially derived from ARV, is essential for establishing proper spacing intervals. Current airspeed information could also enhance situation awareness for trailing aircraft. One proposed spacing concept attempts to achieve a constant threshold-crossing interval for a stream of landing traffic. Prior to reaching the final approach fix, the trailing aircraft is required to maintain a specified time spacing behind the lead aircraft, consistent with safety. The time spacing is based on the difference in final approach speeds between the lead and trailing aircraft after passing the final approach fix (when the aircraft is configured for landing) and the current wind conditions

ARV information notifies the trailing aircraft to speed changes initiated by the lead aircraft. These speed changes could be part of ATC clearances or associated with unplanned speed reductions (e.g., for required arrival timing). Situation awareness resulting from ARV information should enable trailing aircraft flight crews to take necessary actions to prevent separation loss.

ARV broadcasts enable wind estimation. Wind affects the amount of time in which the differences in final approach speeds act to close or stretch the gap between aircraft after passing the final approach fix. For example, a strong headwind would leave more time for a faster trailing aircraft to close the gap between a slower lead aircraft. Inaccurate wind information will lead to greater variability in threshold crossing time, thereby reducing efficiency.

G.2.2.2 Possible ARV Broadcast Condition

In order to support in-trail spacing applications and to provide appropriate situation awareness information to aircraft in an arrival stream, the following ARV broadcast condition may be needed:

> ARV information should be broadcast at a rate consistent with that for ADS-B state vectors when engaged in certain in-trail separation applications as indicated by an appropriate ADS-B service level or by other means such as pilot input. The ARV information should continue to be broadcast until an appropriate signal or condition occurs that signifies the end of the separation application.

G.2.2.3 Air Referenced Velocity Acquisition, Update Interval and Acquisition Range

Air referenced velocity (ARV) proposed update periods and acquisition range requirements are summarized in Table G-1. These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting ARV on-condition reports within the specified acquisition range or time interval.

<u>Note:</u> *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for closest point of approach. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

<u>Table G-1:</u> Summary of Air Referenced Velocity Report Acquisition Range and Update Interval Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**			
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**
Equipage Class →	A1 required	A1 required	A2 required	A3 required
ARV Acquisition Range	NA (see note)	20 NM	40 NM	90 NM
ARV Nominal Update Period (95%) when ground referenced velocity data not available	5 s	7 s	12 s	12 s

<u>Note:</u> *This row is meant to specify the minimum acquisition ranges for all class A equipage classes. Since A1, A2, and A3 equipment all have minimum acquisition ranges greater than 0 NM, no requirement is specified in this cell.*

The following update rates apply when an ARV report is required:

a. The ARV report's nominal update interval should be 5 seconds for A1, A2, and A3 equipment at ranges of 10 NM and closer.

b. The ARV report's nominal update interval should be 7 seconds for A1, A2, and A3 equipment at ranges greater than 10 NM and less than or equal to 20 NM.

c. The ARV report's nominal update interval should be 12 seconds for A2 equipment at ranges greater than 20 NM and less than or equal to 40 NM.

d. The ARV report's nominal update interval should be 12 seconds for A3 equipment at ranges greater than 40 NM and less than or equal to 90 NM.

The ARV report acquisition range in the forward direction should be:

a. 20 NM for equipage class A1,
b. 40 NM for equipage class A2, and
c. 90 NM for equipage class A3.

The acquisition range requirements in directions other than forward should be consistent with those stated in Note 3 of Table 3-34.

For air-to-air use of ARV to potentially support spacing applications, the received update rates for wind speed and direction broadcasts are a 15 second 95% update interval for lead-trail aircraft distances less than 10 NM, and a 30 second 95% update interval for nearby aircraft less than 20 NM away.

G.3 Summary

ARV information is likely to be most beneficial to equipped aircraft engaged in certain applications, such as those described above. Further application usages of ARV broadcasts may be identified in future MASPS revisions. Periodic low-rate ARV broadcast may also enable coarse wind predictions that can be used to improve back-up surveillance necessitated by the loss of ground track or ground speed information. Further research done on potential benefits of ARV information and the required update rates and conditions needed to achieve those benefits could lead to ARV reporting requirements in future MASPS.

References

[1] "Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (AUTOMET)," RTCA, DO-252, Washington, 2000.

[2] Rose, A., "The Airborne Impact of Mode S Enhanced Surveillance and Down-linked Aircraft Parameters," Eurocontrol, SUR3.82.ST03.2150, Nov. 1999, p. 24.